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SOFT WINTER WHEAT STUDIES. II. EVALUATING EXPERIMENTALLY MILLED FLOURS WITH THE AID OF VISCOSITY, FERMENTATION, AND BAKING TESTS

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Introduction

In many mill and other commercial laboratories handling soft winter wheat flours, some type of a torsion viscosimeter may be commonly found. A great deal of reliance is placed upon the so-called viscosity test by many laboratory men who have found the test a very useful tool in control work. Furthermore, some flour buyers now specify a certain viscosity for their purchases, in addition to the more commonly used protein and ash percentages. Some workers, on the other hand, consider the making of viscosity tests as more or less a waste of time. Such a divergence of opinion regarding the value of the test is undoubtedly due to the use of a multiplicity of methods upon a colloidal system. Any such system is very readily influenced by the many factors going to make up its environment. A rigidly controlled technique is therefore required if concordant results are to be obtained by various workers. Such conditions have been lacking in the past with practically every laboratory using its own method.

The present paper is an outgrowth of an effort to produce a standardized viscosity procedure for use in evaluating soft wheat flours. Recently the author (1933a) reported results of a collaborative viscosity study in which commercially-milled flours alone were employed. The results presented at this time deal with flours milled experimentally from pure wheat varieties grown in various parts of Ohio in 1932. It seemed

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desirable to determine the value of the viscosity test in the evaluation of winter wheats being grown experimentally at the present time. From such experimental wheat and its flour, the results indicate the practices which must be followed if wheat of the desired quality is to be produced by the farmer for the Trade. A second object in running these viscosity tests was to determine, if possible, the relative value of the viscosity test as compared with certain other standard tests employed at the present time. The baking test gives the final judgment of strength for flours which are to be used in products produced by a fermentation process. The baking test, however, is laborious and time-consuming. In addition, it is not as well adapted for some very weak flours as it is for the stronger flours used in bread production. A suitable viscosimetric procedure appeared to offer possibilities for a rapid and accurate test for gluten strength, particularly for the weak flours which respond rather unfavorably when subjected to the baking test.

Methods and Material

In this investigation an improved MacMichael viscosimeter was used. This device appears to be the one most commonly used by the soft wheat flour trade. Its use was undoubtedly stimulated by the publication of the earlier researches of Sharp and Gortner (1923) and other workers. While other viscosimeters have proven satisfactory (Rich, 1932), the use of various types will prevent the obtaining of comparable data. To obtain such comparable results it would be necessary to convert all data to absolute units, and Hatschek (1928, page 233) indicates that there is some doubt as to the possibility of doing this. By using one type of viscosimeter, satisfactory relative results are readily obtained, provided an empirical procedure is strictly adhered to. The tentative procedure outlined by the Subcommittee on the Viscosity Test for Soft Wheat Flours (Bayfield, 1933a) was followed in the viscosity determinations reported at this time. It was found, however, that to bring these experimentally milled flours to maximum viscosity more lactic acid was needed than was the case with the commercially milled flours used by the Subcommittee. These experimentally milled flours received 5 instead of 4 increments of normal lactic acid or a total of 9 cubic centimeters. The increments were 1, 2, 2, 2, 2 cubic centimeters, respectively. Additional acid beyond the fifth increment produced no further increase in viscosity. For the sake of brevity, the obtained number of degrees MacMichael is referred to as the "viscosity" of the sample. No allowance has been made for any plasticity in the acidulated flour-water suspensions.

Details of the fermentation and baking tests, for which data are presented, will be given at a later point in this paper. All other analytical

data was obtained by methods approved by the American Association of Cereal Chemists (1928). A 15% moisture basis was used throughout in converting the percentages for protein, ash, and absorption, to a uniform moisture basis. Similarly the flour yields refer to the yield of flour containing 15% of moisture.

The samples were milled on an experimental Allis-Chalmers mill by an experienced practical miller. The average flour yield for the 100 samples was 73.7%. This flour yield is the percentage of 15% moisture content straight grade flour based on the weight of cleaned and tempered (15.5% moisture content) wheat used in the milling sample. In other words, on the average, 73.7 gms. of 15% moisture flour resulted from every 100 gms. of 15.5% moisture wheat milled. The flour yield did not include a varying amount of low grade flour which was discarded. To have added all of this material to the straight grade flour used in these tests would have raised the ash content to excessive figures. However, low ash samples received a small amount (up to 5%) of the low grade flour to bring the ash content up to approximately .43%–.45% ash. Considerable difficulty was experienced in keeping the ash content down to this point in many of the 1932 crop samples. The flours, very probably, approximated a 95% extraction in most cases.

The 100 samples used in this study consisted of ten varieties: Trumbull, Nabob, Fulhio, Red Rock, American Banner, Bald Rock, Michigan Amber, Kharkov, Fultz, and Gladden. Excepting American Banner, these are all red wheats. The Kharkov strain grown in this series seems to have lost its typical hard red winter characteristics and now apparently is a semi-soft type of winter wheat. This is rather unfortunate as this variety was originally placed in the experiment to provide a hard winter wheat check for comparison with the soft winter varieties grown in the series. All of the ten wheats were grown at each of 10 different Ohio locations in 1932, and were a part of a more extensive series grown under the program of the Tri-State Soft Wheat Improvement Association (Bayfield, 1933b).

The wheat samples were grown and selected so that the data resulting therefrom could be considered from two viewpoints: (1) as a varietal study, and (2) as a study of the effect of varying environments. Examination of the data indicates that the effect of location (varying environment) is much greater than that produced by variety. This, of course, is what might be expected. It is of interest to know, however, that a given variety tends to occupy approximately the same relative position in regard to the rest of the varieties in the series at all locations. Some varieties do tend to vary more than others and this is an undesirable character. Both Michigan Amber and Nabob must be criticized in this regard. Very probably these varieties are heterozygous for the

characters which go to make up the "quality" of the wheat. Worzella (1933) has been able to isolate 43 different strains from Michigan Amber. To avoid the distribution of varieties possessing a variable quality or, in other words, possessing the ability to respond readily to environmental changes, the plant breeder will have to pay more attention to the quality of the new wheats which he is producing. This is more difficult to do than to merely make the selection based upon the outward morphological characteristics of the plants. Uniformity in the wheat going to the rolls makes for uniformity in the flour.

The statement has already been made that the baking test gives the final judgment regarding the strength of the sample. For experimentally milled soft winter wheat flours Bayfield and Shiple (1933) have shown that the so-called basic baking procedure of the A. A. C. C. is not well adapted for determining strength. They found that a variable instead of a fixed absorption, 3.5 instead of 2.5 gms. of sugar, and the use of 1 mgm. of potassium bromate produced test loaves with volumes in closer agreement with the protein content than did the basic baking formula. Further work since publication of the above paper indicates that 5.0 gms. of sugar per loaf gives further improvement (Bayfield, 1933b). It also appears that 1 mgm. of potassium bromate is sufficient excepting for abnormally high protein samples (for Ohio). Such samples result from certain fertilizer treatments (Bayfield, 1933c), but do not reach mills in any large volume.

Baking data in this paper were obtained through the use of the following modified formula:

Formula

Flour	100 gms. (15% moisture basis)
Sugar	5 gms.
Salt	1 gm.
Yeast	3 gms.
Water (distilled)	Varied to correct absorption
Potassium bromate	1 mgm.
Fermentation times	As required in A. A. C. C. basic procedure
Fermentation temperatures	As required in A. A. C. C. basic procedure

Baked at 230° C. ± 5° for 30 minutes

Loaf volumes were determined by displacement in the customary manner. Duplicated bakes had to agree within 20 cc. in loaf volume or be repeated. All replicated bakes were made on different days. Internal loaf scores were obtained by following as closely as possible the methods advocated by Blish and co-workers (1928), and Harrel and co-workers (1929). In addition it will be noticed in Tables I and II that a crust color score is given. This score was used as a rough measure of the diastatic activity or residual sugar remaining in the loaf at time of baking. A crust score of 10 points is considered the optimum color and indicates sufficient residual sugar. A score over 10 means too dark a

TABLE I

CHARACTERISTICS OF WHEAT VARIETIES [1]

Variety	Wheat			Flour				Baking Test				
	Test weight	Flour yield	Protein in wheat	Protein in flour	Ash in flour	Absorption	Maximum viscosity [2]	Loaf volume	Grain	Texture	Color of crumb	Crust color [3]
	Lbs.	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*°MacM.*	*Cc.*				
Red Rock	60.5	73.8	10.8	9.5	.52	57.7	67.7	587	100.1	99.2	99.9	8.7
Trumbull	60.2	74.0	11.1	9.9	.48	55.7	77.1	586	98.7	99.3	98.7	8.5
Fulhio	60.3	74.3	11.1	9.9	.48	55.6	73.6	583	99.0	98.7	98.5	8.6
Michigan Amber	59.3	73.4	11.3	10.0	.52	57.7	64.4	583	98.2	98.1	97.9	8.6
Bald Rock	60.0	73.6	11.0	9.6	.50	56.5	66.9	580	98.7	98.3	98.7	8.4
Kharkov	59.8	73.3	10.9	9.6	.50	55.9	55.6	573	98.0	98.4	97.8	8.5
Nabob	60.5	74.1	10.7	9.4	.49	55.6	55.9	563	98.3	97.9	98.5	9.1
Fultz	59.7	73.2	10.8	9.4	.51	56.3	59.8	560	98.6	98.2	97.9	8.6
Gladden	59.7	73.3	10.6	9.1	.47	54.6	53.5	554	97.8	97.5	97.5	8.3
American Banner	58.6	73.7	10.0	8.5	.48	53.6	37.9	539	96.9	96.9	96.9	8.3
Average	59.9	73.7	10.8	9.5	.50	55.9	61.2	571	98.4	98.2	98.2	8.6

[1] The data for a single variety represent averages for 10 locations.
[2] Viscosity using 9 cc. normal lactic acid.
[3] Crust color scores: 10 points equals optimum score.

TABLE II

AVERAGE CHARACTERISTICS OF WHEAT FROM VARIOUS LOCATIONS[1]

Location No.	Wheat			Flour				Baking Test				
	Test weight	Flour yield	Protein in wheat	Protein in flour	Ash in flour	Absorption	Maximum viscosity[2]	Loaf volume	Grain	Texture	Color of crumb	Crust color[3]
	Lbs.	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*°MacM.*	*Cc.*				
1	58.3	74.3	9.6	8.3	.46	55.7	47.4	520	99.2	98.3	98.3	6.7
2	58.6	75.0	9.1	8.0	.45	54.4	47.5	526	99.3	98.9	98.4	5.9
3	60.5	74.0	9.5	8.2	.45	55.5	52.1	537	99.0	99.0	100.0	8.7
4	58.9	74.3	10.2	8.8	.46	55.4	52.1	518	97.7	97.1	97.2	8.0
7	60.4	73.8	12.8	11.4	.55	56.0	84.4	639	98.2	98.9	97.4	10.2
8	60.3	73.6	12.6	11.3	.53	55.2	71.6	593	97.7	97.8	97.7	9.8
9	61.1	73.7	10.4	9.1	.50	55.8	48.3	564	98.1	97.9	98.3	8.3
10	61.0	73.2	12.5	11.2	.59	58.2	65.2	616	98.4	99.3	98.5	9.4
11	60.0	72.5	12.1	10.8	.51	57.1	90.2	632	99.0	97.6	98.8	10.1
12	59.4	72.5	9.6	8.1	.45	56.0	53.6	561	97.7	97.7	97.7	8.5
Average	59.9	73.7	10.8	9.5	.50	55.9	61.2	571	98.4	98.2	98.2	8.6

[1] The data for a single location represent averages for 10 varieties.
[2] Using 9 cc. normal lactic acid.
[3] Crust color scores: 10 points equals optimum color.

crust, indicating more sugar present than needed. A score below 6 indicates a definite deficiency in sugar content. While these crust color scores are approximations only, yet they do appear to be of value. With scores below 6 points the true strength of the gluten may be masked by a lack of gas in the dough.

It is realized that the formula and method is one which taxes the gluten of a soft wheat flour rather severely, yet the procedure was designed to do this. The long fermentation period with plenty of sugar and yeast required a good quality of gluten if the flour in question was to stand up. Those that did, produced excellent appearing bread.

Experimental Results

In Table I are presented data for the samples averaged according to variety of wheat. The varieties are given in the table in order of descending loaf volume. This ranks the varieties for strength satisfactorily, with the exception that Fultz normally ranks higher and Michigan Amber lower than they do in the present crop. Red Rock is somewhat relatively weaker than expected when compared with the check variety, Trumbull. It may be observed that the spread in loaf volume, being only 48 cc., is not large. The viscosity figures do not rank the varieties quite the same as loaf volume but the agreement is fairly good and the spread is considerable which is a decided advantage.

Viscosity data need to be considered in conjunction with the protein and ash percentages. For example, Red Rock, according to the viscosity figure, is weaker than Trumbull or Fulhio. When the relative amounts of protein and ash present are considered in these three varieties the reason for the very favorable rating for Trumbull and Fulhio at once becomes apparent. Red Rock contains less protein and more ash than the other two varieties, and both of these factors tend to reduce viscosity values. Similar comparisons could be easily made for other varieties. It is interesting to observe the inferior performance of the protein in Michigan Amber as compared with that of Red Rock, and also the very distinctive behavior in viscosity of the white variety, American Banner, as compared with all the other varieties in the series.

Table II gives the averages which resulted from grouping together all 10 varieties grown at each individual location. Thus each average figure contains the results from one sample of each of the 10 varieties in the series. An examination of this table indicates the effect of a spread of 3.4% in flour protein upon the other data, such as loaf volume and viscosity values. A comparison of the data shown in Tables I and II indicates that environment is a more potent influence than variety in producing variations in crop quality. Table II also gives a suggestion as to the relative influence upon wheat strength of soils as compared with

climates in a season such as 1932. Locations 1 to 4 inclusive consisted of plots grown on *different* soil types under a *uniform* climate, while locations 7 to 12 inclusive were on *medium* textured soils located *across* the climatic zones of Ohio. The large effect of environment upon diastatic activity as depicted by crust color is worthy of notice.

The relative rankings of the various locations in order of strength when ranked by viscosity values, loaf volume measurements, or protein contents are in reasonable agreement. Location 12 is more out of line than any other. Possibly the milling behavior of these samples was somewhat different. A shorter extraction in the case of location 12, with probably a somewhat better temper on the wheat may account for the favorable showing of these samples as compared with those from locations 1, 2, and 3 which are in a similar protein range.

The Viscosity Test

Table III gives the detailed viscosity data for the 10 varieties. Table IV presents the same data arranged according to location or to wheat origins. Both tables give the viscosity increases which result from the different increments of added acid. Thus in Table III, the 1 cc. viscosity increase for Red Rock is the difference in viscosity reading obtained by adding 1 cc. of lactic acid ($17.2° - 12.1° = + 5.1°$). The 3 cc. increase equals $30.7° - 17.2°$ or an increase of 13.5° MacM. In commercial practice it is customary to graph the viscosity increase data, plotting viscosity increase as ordinates against number of increments of acid used as abscissae.

The commercial interpretation of the viscosity data is of interest. Mr. Edgar L. Ulrey, before the Cincinnati Division of the Central States Section of the A. A. C. C., expressed it as follows (personal communication, August, 1932):

"We find this to be a very good test for determining quality and quantity of gluten, using the maximum reading as an indication of quantity and the viscosity increases indicating quality. With the first 3 increases we plot a curve, which gives a good picture of the flour. For example, a short patent flour made from Indiana soft red winter wheat may have a total viscosity of 80, the five readings would be:

Cc. of normal lactic acid	0	1	3	5	7
Viscosity reading	15	60	75	78	80
Viscosity increases		45	15	3	2

A clear flour made at the same time as the above short patent would probably have the following viscosity:

Cc. of normal lactic acid	0	1	3	5	7
Viscosity reading	12	25	70	75	80
Viscosity increases		10	45	5	5

The short patent had a protein content of 8.00 per cent and an ash content of 0.33 per cent while the clear flour possessed a protein content of 9.25 per cent and an ash content of 0.48 per cent."

Mr. Ulrey's method of interpretation seems to be the method normally used by quite a number of workers using the several increment viscosity procedure. Convexity in the viscosity increase curve indicates a high buffering action due to the ash content being high. When the ash content is over 0.50%, irregular shaped viscosity increase curves are likely to result. It is difficult to interpret the meaning of such curves. In fact, some users of the test claim that it is not suited to such high ash flours.

An examination of the viscosity increase curves obtained from plotting the data given in Tables III and IV indicates that a large percentage of these experimentally milled flours give curves which do not agree with those given by commercially milled flours. A great many experimentally milled flours produce a curve which is concave between the 1 cc. and 5 cc. increments and then drops from the 5 cc. to 9 cc. points. These irregular shaped curves are not entirely restricted to the higher ash content levels. Therefore, it appears that some other factor or factors besides ash and protein are acting. The author believes that this factor is probably a differential in granulation. More or less imperfect removal of the wheat germ in experimental milling may also enter into the problem.

These experimentally milled flours looked and felt more granular than commercial flours from the same class of wheat. Pascoe, Gortner, and Sherwood (1930) found a similar difference with hard wheats. That granulation differences are entering into the problem was indicated from the behavior of the samples while the determination was being carried out. It was observed that the 3 cc. increment point was relatively less stable than later increment points; the 1 cc. increment point was the one which gave the greatest amount of trouble in checking the results. It seems reasonable to assume that sufficient time must elapse for the larger granules to imbibe the required amount of water and thus to make the ash and protein available for action with the lactic acid; otherwise the viscosity reading represents only part of the true colloidal condition. The smaller and most easily hydrated particles would be the most active in giving the first readings. The larger granules would be influential later in the test. Sasse and Pearson (1930) experienced difficulty in obtaining check results with a short time viscosity method due to granulation differences and recommended having the suspensions stand for an hour previous to running the viscosity test. Apparently it would be desirable to give experimentally milled samples an opportunity to hydrate before determining their viscosity. That this feature so far has not been found necessary for commercial soft winter wheat flours is probably due to their greater degree of refinement and more uniform granulation than was the case with the experimentally milled flours dis-

TABLE III

THE INFLUENCE OF WHEAT VARIETY UPON VISCOSITY[1]
(*Varieties arranged in order of decreasing loaf volume*)

Variety	Viscosity in degrees MacMichael						Increase in viscosity from addition of acid (°MacM.)				
	Amount of acid used						Amount of acid used				
	0 cc.	1 cc.	3 cc.	5 cc.	7 cc.	9 cc.	1 cc.	3 cc.	5 cc.	7 cc.	9 cc.
Red Rock	12.1	17.2	30.7	51.1	62.5	67.7	5.1	13.5	20.4	11.4	5.2
Trumbull	11.5	20.4	39.1	61.6	72.5	77.1	8.9	18.7	22.5	10.9	4.6
Fulhio	11.0	17.2	38.2	59.7	69.9	73.6	6.2	21.0	21.5	10.2	3.7
Michigan Amber	11.7	24.4	26.6	46.1	58.6	64.4	12.7	2.2	19.5	12.5	5.8
Bald Rock	10.9	22.7	27.9	48.2	60.0	66.9	11.8	5.2	20.3	11.8	6.9
Kharkov	12.0	25.9	28.6	42.2	51.3	55.6	13.9	2.7	13.6	9.1	4.3
Nabob	10.0	15.1	26.0	43.1	52.2	55.9	5.1	10.9	17.1	9.1	3.7
Fultz	12.5	24.9	29.1	45.5	55.5	59.8	12.4	4.2	16.4	10.0	4.3
Gladden	15.0	23.6	31.7	43.9	50.6	53.5	8.6	8.1	12.2	6.7	2.9
American Banner	9.4	13.8	19.7	29.2	35.0	37.9	4.4	5.9	9.5	5.8	2.9
Average	11.6	20.5	29.8	47.1	56.8	61.2	8.9	9.2	17.3	9.7	4.4

[1] The data for a single variety represent averages for 10 locations.

TABLE IV

THE INFLUENCE OF VARYING WHEAT ORIGINS UPON VISCOSITY [1]

Location	Viscosity in degrees MacMichael						Increase in viscosity from added acid (°MacM.)				
	Amount of acid used						Amount of acid used				
	0 cc.	1 cc.	3 cc.	5 cc.	7 cc.	9 cc.	1 cc.	3 cc.	5 cc.	7 cc.	9 cc.
1	10.7	12.2	24.1	37.7	44.8	47.4	1.7	11.9	13.6	7.1	2.6
2	10.8	14.1	27.0	39.5	45.6	47.5	3.3	12.9	12.5	6.1	1.9
3	10.4	15.6	29.4	43.0	49.9	52.1	5.2	13.8	13.6	6.9	2.2
4	10.3	15.6	27.0	41.2	48.9	52.1	5.3	11.4	14.2	7.7	3.2
7	12.1	28.7	38.3	63.6	77.7	84.4	16.6	9.6	25.3	14.1	6.7
8	12.4	27.2	31.4	53.1	65.7	71.6	14.8	4.2	21.7	12.6	5.9
9	10.1	17.5	19.4	34.1	43.3	48.3	7.4	1.9	14.7	9.2	5.0
10	12.6	32.5	22.0	43.0	57.1	65.2	19.9	−10.5	21.0	14.1	8.1
11	16.4	29.5	51.8	73.5	85.0	90.2	13.1	22.3	21.7	11.5	5.2
12	10.3	12.3	27.2	41.9	50.1	53.6	2.0	14.9	14.7	8.2	3.5
Average	11.6	20.5	29.8	47.1	56.8	61.2	8.9	9.2	17.3	9.7	4.4

[1] The data for a single location represent averages for 10 varieties.

cussed in this paper. Many of these experimental flours are considerably higher in protein than the average soft wheat flours on the market and this would also tend to increase the time required for imbibition due to the higher degree of vitreousness associated with the increase in protein (Bayfield, 1933d).

A certain amount of statistical analysis was done with the viscosity data in order to study the relative effects of protein and ash. Table V gives the values obtained for these relationships dealing with both the actual viscosities and the viscosity increases. It will be observed that both total and partial correlations have been used. Partial correlations are very handy tools for eliminating the influence of a given factor. For example, the effect of varying amounts of protein or ash may be eliminated by this mathematical means.

TABLE V

A Statistical Study of the Effect of Protein and Ash upon the Viscosity Results

Amount lactic acid used	Correlation coefficient between [1]			
	Viscosity and protein	Viscosity and protein, holding ash constant	Viscosity and ash	Viscosity and ash, holding protein constant
Cc.	*r*	*R*	*r*	*R*
1	+.6922	+.3605	+.7139	+.4254
3	+.2547	+.7932	−.3514	−.5365
5	+.4707	+.8428	−.1411	−.7972
7	+.6045	+.8469	+.0316	−.7451
9	+.6579	+.7999	+.1588	−.6172

Amount lactic acid used	Viscosity increase and protein	Viscosity increase and protein, holding ash constant	Viscosity increase and ash	Viscosity increase and ash, holding protein constant
Cc.	*r*	*R*	*r*	*R*
1	+.6321	+.0208	+.7369	+.5215
3	−.4399	+.0115	−.6845	−.5913
5	+.7090	+.6584	+.3884	−.2618
7	+.7705	+.4812	+.7700	+.4798
9	+.6763	+.8348	+.1506	−.6737

[1] Coefficients less than .195 lack statistical significance, with odds less than approximately 1:20.

That protein content and viscosity are positively correlated is a well known fact. Rich (1932), with Western Canadian hard spring wheats, obtained coefficients ranging from + .739 to + .947 for these two factors. The wheats used by this investigator contained, very probably, a more uniform protein quality than existed among the 10 varieties grouped together to make up the samples reported in this paper. This lack of uniformity in protein quality would tend to reduce the magnitude of the coefficient between crude protein and viscosity. Larmour

and Sallans (1933) have recently published high coefficients which they found existing between protein content and viscosity. These investigators worked with experimentally milled pure Marquis wheat which ranged in protein content from 8.2 to 18.3%.

Ash content has been shown to act inversely to protein in its effect upon viscosity. In other words, ash and protein are two forces acting in opposite directions in so far as viscosity is concerned. The true relationship between protein and viscosity is therefore not given until the effect of ash is eliminated. Similarly, the effect of protein needs to be eliminated in studying the effect of ash upon viscosity.

In calculating these total and partial correlation coefficients the individual values were collected in frequency tables which, owing to their bulky nature, have not been included. The total correlation coefficient r was obtained from the formula

$$r_{xy} = \frac{\Sigma(xy/n) - xy}{\sigma_x \sigma_y},$$

while the partial correlation coefficient R was obtained from

$$R_{xy.z} = \frac{r_{xy} - (r_{zx})(r_{zy})}{\sqrt{(1 - r_{zx}^2)}\sqrt{(1 - r_{zy}^2)}},$$

where Σ denotes summation, $\bar{x}$ and $\bar{y}$ = means of x and y respectively, and σ denotes the standard error. Furthermore the coefficients were not considered significant unless they were as great as, or greater than, three times their probable errors. With N equaling 100, the coefficient has to be greater than .195 to be significant.

Examination of the data in Table V indicates considerable erratic tendencies, particularly so with the 1 and 3 cc. increments. It would appear that the results from these two increments are not of much value. As has already been mentioned, granulation of the flour and only partial hydration of the protein and starch probably causes these discrepancies. Whether hydration is entirely complete at the time of taking the 5 cc. readings, it is impossible to say at this time. At the time of the 9 cc. readings, however, it must have been complete, or practically so, as additional acid (total 11 cc.) did not give sufficient additional increase in viscosity to offset the decrease due to the dilution caused by adding the two additional cubic centimeters of acid. It may, however, be stated from the results in Table V that protein is significantly and positively correlated with viscosity and that ash content has a decided depressing influence upon the viscosity of the acidulated flour-water suspension.

The Fermentation Test

For many years workers have tried out many different types of tests for estimating the quality of flour. The baking test is slow and ex-

pensive although so far no test has proven its equal for determining strength in flour. Among the more strenuous objectors to the baking test are those who are testing flour to be used for purposes other than bread. Among these may be mentioned macaroni, soda cracker, and cake makers. Many were the tests tried out as a substitute for the baking test. Thus Shepard (1905) used a baker's sponge test on an extensive series of macaroni wheats. Norton (1905) stated that the sponge test gave valuable information regarding water absorption and strength of flours. He was primarily interested in durum wheats. Hays and Boss (1899) reported results from the use of a sponge test for testing hard spring and other types of wheat. Recently, Wilsie, Robinson, and Winter (1932) found that carefully conducted expansion tests could be used for differentiating between soft wheat flours with reasonable accuracy. They worked with Michigan grown American Banner and Red Rock wheats, and placed the greatest reliance on the second rise of a dough in this fermentation test.

The Tri-State Soft Wheat Improvement Association has used a modified and improved sponge test as a possible test for quality with particular reference to quality for cracker production. Data for the 1929 to 1931 crops, inclusive, have been given in the annual reports of the Association. Statistical and other studies made by the author upon these data indicate that the sponge test is not as reliable a test of strength as is the baking test. However, the test does throw some light upon the characteristics of a given flour. The test readily separates flours of widely varying strengths into groups according to their strength, but is not so satisfactory in making more refined separations.

This fermentation test is carried out as follows: A dough is made up exactly the same as for a baking test excepting that no bromate is used. In fact in making non-bromated bakes frequently one-half of a 200-gram (of flour) dough is used for the fermentation test. The dough is carefully inserted into a 1000 cc. Chidlow jar. A cloth cover is then placed over the jar before placing it in a specially constructed fermentation cabinet automatically regulated for temperature (30° C. $\pm$ 2°) and relative humidity (90% $\pm$ 5%). Fermentation commences at once. Starting at the end of the first hour, the height of the dough is recorded every 15 minutes. When the dough either falls or ceases to gain in height, the jar is removed and the dough in punched. After being replaced in the jar as before, the dough is again allowed to rise for a second time, readings being recorded every 15 minutes. When no further rise occurs the test is completed. The various readings are then plotted on squared paper with fermentation times as abscissae and dough volumes as ordinates. It has been found satisfactory to use 200 cc. and 60 minutes as the point of origin. The area beneath the resulting curve

is measured by means of a planimeter reading in square centimeters. The area for the first and second rises is determined and the sum of both rises gives the figure " A " in Table VI.

TABLE VI

THE EFFECT OF ORIGIN AND VARIETY UPON FERMENTATION TOLERANCE [1]

Variety or Location	Fermentation		Dough volume		Planimeter readings		
	Time 1	Time 2	1st rise	2d rise	1st rise	2d rise	"A"
	Min.	*Min.*	*Cc.*	*Cc.*	*Cm.²*	*Cm.²*	*Cm.²*
Red Rock	76.6	115.5	589.5	845.0	12.8	94.3	107.1
Trumbull	85.6	111.7	637.0	818.0	22.0	91.0	113.0
Fulhio	93.0	117.8	651.5	853.5	27.9	96.7	124.6
Michigan Amber	82.5	88.5	610.0	727.0	21.2	55.9	77.1
Bald Rock	76.7	106.5	597.0	736.5	13.9	74.7	88.6
Kharkov	90.9	104.2	672.5	786.0	27.9	74.0	101.9
Nabob	80.4	118.4	604.0	817.5	16.5	97.7	114.2
Fultz	79.6	102.1	620.5	773.0	16.8	72.4	89.2
Gladden	89.5	109.3	676.0	820.0	24.8	84.2	109.0
American Banner	87.9	102.0	628.0	735.0	23.2	66.7	89.9
Average for all varieties	84.3	107.6	628.6	791.1	20.7	80.8	101.5
Location 1	92.4	102.1	689.0	795.5	29.3	70.8	100.1
" 2	92.4	93.8	682.0	759.5	28.4	64.7	93.1
" 3	94.6	117.6	649.5	834.0	30.0	96.4	126.4
" 4	90.1	115.4	669.5	798.0	24.4	87.7	112.1
" 7	73.7	98.3	561.5	756.5	9.9	71.8	81.7
" 8	75.1	90.9	539.0	724.0	11.4	60.9	72.3
" 9	81.8	125.2	604.5	832.0	19.2	107.9	127.1
" 10	69.8	111.7	539.0	780.5	7.4	84.4	91.8
" 11	82.6	110.9	664.0	817.0	20.0	85.3	105.3
" 12	90.2	110.1	688.0	814.5	27.0	77.7	104.7
Average for all locations	84.3	107.6	628.6	791.1	20.7	80.8	101.5

[1] Data for a single variety or a single location represent averages for 10 locations or 10 varieties respectively.

Considering there is an adequate sugar supply available for the yeast, then the A values should give information regarding the ability of a dough to withstand the degenerative influence of the proteolytic enzymes, as well as the strength of the gluten, which is being constantly expanded by the gas generated by the yeast organism. It is probable that 5% of sugar and 3% of yeast provides too active an evolution of gas in the first rise in cases of granular flours which would have insufficient time to imbibe water and to mellow before being torn to pieces by the gas. This may account for many of the dough samples of the 1932 crop falling before the first hour was over. This trouble was not experienced to any large degree with previous crops where less than 5% of sugar was used.

In Table VI are given the fermentation test data averaged by varieties and also according to locations. It will be seen that the varieties

rank themselves quite differently if arranged according to their fermentation values, and not as arranged in the table (according to loaf volume). This is the same type of comparison as that obtained with preceding crops when comparisons between fermentation test and loaf volume ratings have been attempted.

In the present instance the author was principally interested in the relationship, if any, between the fermentation test and viscosity. Examination of fermentation and viscosity increase curves obtained from individual samples seemed to indicate that most of the samples of dough which fell before the first hour was up also gave a sharp falling off in viscosity at the 3 cc. point. To see whether there actually was any relationship between these two features, and also for the purpose of studying several other points, the statistical analysis presented in Table VII was undertaken.

TABLE VII

SOME FERMENTATION TEST STATISTICAL RELATIONSHIPS

Factors held constant		None	Crude protein (flour)	Ash (flour)	Crude protein and ash
Correlation between					
x	y	r [1]	R [1]	R [1]	R [1]
"A"	C.P. (flour)	−.3030	——	——	——
1st rise	C.P. (flour)	−.4542	——	−.2212	——
1st rise	Ash	−.4369	−.1745	——	——
1st rise	Viscosity increase 3 cc.	+.1774	−.0280	−.1856	——
2nd rise	C.P. (flour)	−.1107	——	+.0228	——
2nd rise	Ash	−.1736	−.1365	——	——
2nd rise	Viscosity increase 3 cc.	+.2951	+.2761	+.2456	+.2454
2nd rise	Viscosity 3 cc.	+.1772	+.2137	+.1260	+.1772
2nd rise	Viscosity 5 cc.	+.1304	+.2081	+.1086	+.1661
2nd rise	Viscosity 9 cc.	+.5673	+.8552	+.6118	+.9893
2nd rise	Loaf Volume	−.0429	+.0861	+.0755	+.0845

[1] Coefficients smaller than .195 lack significance, with odds less than approximately 1:20.

It will be observed in Table VII that the 1st rise possessed no statistically significant relationship with the viscosity increase due to adding 3 cc. of lactic acid. There is, however, a low but significant positive relationship between the 2d rise and a viscosity increase at 3 cc. The correlations between ash or protein and the fermentation test values are all low and frequently in the wrong direction from that which might be expected. Apparently the fermentation test bears but little relationship to loaf volume. However, the 2d rise and a viscosity at 9 cc. are highly correlated. It appears from these results that the maximum viscosity gives a good measure of fermentation tolerance in these flours. Provided that further crop data verifies this relationship between the fermentation test and maximum viscosity, it seems that the viscosity test

might well replace the fermentation test. This is of interest to the cracker manufacturer.

Discussion

In order to compare several tests it is necessary to compare them against a common standard. Strength is a good measure for quality in flours which must undergo the action of yeast fermentation during the manufacturing process. Protein content is an excellent measure of protein quantity and a measure which is accurate within a narrow range. Its determination is free from biological or colloidal influences which is not so in the case of viscosity, fermentation, or baking tests. It should, therefore, be a good base for comparing other measures which are more susceptible to errors in the determination.

With the high quality, high quantity protein wheats of Western Canada, Larmour (1931) found that protein content accounted for over 80% of the total variation in loaf volume when a suitable baking procedure was used. The wheats with which the author is working are not likely to show as high a relationship as that found by Larmour (1931) for a number of reasons, among which may be mentioned; (1) a narrower total spread in protein content, (2) a larger number of varieties averaged together with each variety having a different protein quality, (3) a narrower range in loaf volumes with a corresponding greater percentage of error in the determination, and (4) the use of a baking formula which may not as yet be as well adapted to soft wheat flours as the formula which Larmour used was for hard wheats. The effect of improving the formula is brought out by the improvement in the magnitudes of the protein x loaf volume correlation coefficients for the past four seasons' work.

Flour protein and loaf volume correlation for the year	Number of samples	Magnitude of coefficient
1929	100	+.4289
1930	224	+.6136
1931	100	+.6397
1932	100	+.8247

From the above, it will be seen that protein content in the 1932 crop is accounting for approximately 65% of the variation in loaf volume, and this from a diverse group of wheats of varying protein qualities. That protein content is so highly effective as a measure of strength is important because the protein test is relatively easy and speedy to perform. As the author has found crude protein in wheat to be highly correlated with crude protein in the flour from that wheat, a protein determination on the wheat itself gives a fair indication of its future behavior when converted into flour. The value of the protein determination will be

largely dissipated, however, if the wheat is a mixture of varieties possessing unknown protein qualities. This is an important argument in favor of eliminating poor quality protein varieties and the removal of diverse types of wheat within a given area. Once the quality of a variety of wheat is known, then, the protein test may be used as a means for measuring and for predicting the behavior of the flour when subjected to the final production processes.

However, the baking test or some other method must be employed to determine the quality of the protein. At this time the object is to determine which of several tests promises to give the most satisfactory results. Results from such a study are probably best brought out by statistical means. Table VIII indicates a number of relationships between several measures which have been used for measuring quality.

TABLE VIII

SOME STATISTICS INDICATING THE RELATIONSHIP BETWEEN SOME MEASURES OF QUALITY

Factors held constant		None	Protein	Ash	Protein and Ash
Correlation between					
x	*y*	r[1]	R[1]	R[1]	R[1]
Wheat protein	Test weight	+.4538			
	Loaf volume	+.8289			
	Viscosity (9 cc.)	+.6857			
Flour protein	Loaf volume	+.8247		+.7124	
	Viscosity (9 cc.)	+.6579		+.7999	
	"A"	−.3030			
	1st rise	−.4542		−.2212	
	2nd rise	−.1107		+.0228	
	Absorption	+.3931			
	Ash	+.7267			
Loaf volume	Viscosity (9 cc.)	+.7124	+.3987	+.5096	−.1429
	Ash	+.5921	−.0185		
Viscosity 9 cc.	Ash	+.1588	−.6172		

[1] Coefficients smaller than .195 lack significance, possessing odds of less than approximately 1:20.

Table VIII indicates that loaf volume is significantly and positively correlated with both protein content and viscosity. Table VII showed no relationship between loaf volume and the 2d rise in the fermentation test. It would appear that it is the influence of protein and ash which is causing the apparent relationship found between loaf volume and viscosity at 9 cc. Apparently the maximum viscosity (9 cc.) is influenced by the same factors that effect loaf volume although the former is somewhat more susceptible to ash than is the latter. As loaf volume is considered a suitable measure for strength, viscosity may offer some possi-

bilities as a substitute. This conclusion is in agreement with the findings of Larmour and Sallans (1933) who state,

"The actual measurements made on unleached suspensions, or the response to acidulation or to increased flour concentration of the unleached suspensions, give as much differentiation as the bromate baking test."

These authors believe that the baking test will remain for some time to come as the criterion by which other quality tests may be judged. However, with flours of *known protein quality* the protein test itself gives a good indication of the strength of the flour. With new crop wheat or wheat from untested varieties or locations, the protein test will need to be used in conjunction with a measure of quality. Once the quality factor is settled, then the protein determination itself may be used as a control measure for regulating the quantity of protein or strength of the flour.

Summary

A group of wheat varieties grown at several Ohio locations in 1932 showed that variety is much less important than environment as a factor causing variation in quality.

The quality of these wheats was tested by means of baking, viscosity, and fermentation tests. Statistical studies and practical experience indicate these tests to be of value in the order given.

The relationship between crude protein and loaf volume, or between crude protein and maximum viscosity of acidulated flour-water suspensions, was positive and high.

These studies indicate that the viscosity test shows possibilities as a substitute for the bromate baking test for measuring strength. Viscosity also proved to be highly and positively correlated with fermentation tolerance as measured by the second rise of a dough in a fermentation test.

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EFFECT OF NITRATE SALTS SUPPLIED TO WHEAT GROWN IN LIQUID MEDIA ON BREAD SCORES. II

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Introduction

By the production of wheat in aqueous culture media adjusted during the latter growth stage of the crop so as to obtain an array of differences in the character of the sap of the growing crops, the writer [1] has shown that differences in bread scores arising out of the constitution of the protein of the grain, vary with the character of the solutes present in the culture medium during the latter growth phase of the plants. The thesis advanced as explanation of the cause of variation in bread scores, due to the quality of protein, was that the physical state of wheat protein (and possibly, in a minor degree, starch) was determined by the nature of the salt solution surrounding the protein during its synthesis and translocation into the grain. It was assumed that the physical state of the protein determines strength of flour as used in bread making. Variation in this property was furthermore assumed to be due to the nature of the arrangement of the protein molecules or certain of their aggregates, which would vary with the nature of the salt solution in which their formation occurs. The salt solution is the plant sap, and its character is determined by the solutes absorbed by the plants. Quality in bread varies with the amounts of protein in the flour; consequently it was necessary in an investigation on " factors that affect the quality of protein " to eliminate any effect which quantitative differences in the composition of flour may have on bread scores. To obtain samples alike in percentage of protein in the grain, but unlike as to the character of the sap in which it was synthesized, it was found expedient to devise methods that would differentiate the material into two classes, high-protein grain and low-protein grain. The former was obtained by cultural conditions which provided ample nitrogen throughout the entire growth period of the crop; the latter by those which precluded nitrogen in the culture medium of the crop during the latter part of the growing

[1] Gericke, W. F. 1933. Variation of protein quality in wheat grown in aqueous culture media. Cereal Chem. **10**: 347–359.

period. This paper deals with the bread scores obtained from high-protein wheat. Samples were obtained by providing the growing crop during its latter growth phase with one of the following nitrate salts: NH_4NO_3, $Ca(NO_3)_2$, KNO_3, $Mg(NO_3)_2$, and $NaNO_3$ with the exclusion of all other elements required in a complete nutrient solution. It is by the restriction of the mineral absorption of plants to one salt that the character of the sap can be markedly altered from the type obtained when vegetation is rooted in a complete culture medium. Obviously such treatment must be restricted to the latter growth phase of the plants and after a certain state of vegetative development has been obtained that will permit grain production without any further supply of inorganic elements.

It was pointed out in previous papers [2, 3] that, by preclusion of inorganic nutrients during the latter growth stage of wheat (and other crops), the causal relation between the quantities of any nutrient absorbed and the yield obtained can be established. The differentiation of the total quantity of any nutrient absorbed into two fractions, one which is absorbed during the early growth stage and another absorbed during the latter part of the growth stage, provides the mechanics whereby the effects of the character of the sap of wheat on bread scores can be determined.

Experimental

The data given in this paper are the bread scores of a series of wheat cultures in which the only inorganic element available for absorption, apart from nitrogen, was one of the following cations: NH_4, Ca, K, Mg, and Na. Brief description of the technique employed in growing wheat in liquid media on a scale sufficiently large to obtain samples for milling and baking operation has appeared in previous publications.

The cultures were treated alike until the appearance of the first visible portion of the head, which was April 1; the seeding of the crop having been made January 5. Thus the cultures were scarcely three months old when the complete nutrient solution provided by the fertilizing units placed in the tanks of water was removed. The tanks were twice filled with water and drained after the original culture solution was removed, in order to reduce to minimum concentration such salts from the complete nutrient solution as may adhere to the roots. Nitrate salts were added at the third filling of the reservoirs. The quantity supplied was far in excess of the amount the plants could possibly absorb. Reservoirs 10 feet long, 2½ feet wide, and 8 inches deep, filled with water, each received 3.4 mols of the respective nitrate salts. The cultures

[2] See footnote 1.
[3] Gericke, W. F. 1933. Bread quality of wheat produced in aqueous culture media. Science 77: 229–232.

TABLE I [1]

EFFECT OF VARIOUS NITRATE SALTS ON BREAD SCORES OF WHEAT (BUNYIP) GROWN IN AQUEOUS CULTURE MEDIA UNDER GLASS

Sample number	Treatment during latter growth stage of crop [2]	Test weight (before scouring)	Protein		Ash in flour	Bread volume		Color		Texture		Grain		Crust [3]		Oven spring [4]	
			Wheat	Flour		Initial	Stimulated	Initial	Stimulated	Initial	Stimulated	Initial	Stimulated	Initial	Stimulated	Initial	Stimulated
		Lbs.	*P.ct.*	*P.ct.*	*P.ct.*	*Cc.*	*Cc.*	*Score*	*Score*	*Score*	*Score*	*Score*	*Score*	*Score*	*Score*		
	All essential elements entire growth period (*control sample*)	61.0	15.2	13.8	.52	630	645	99	100	98	97	99	97	9	9	Good	Good
2	NH_4NO_3 to maturity	58.0	17.0	15.4	.49	675	745	97	98	97	97	94	95	8	8	Very good	Very good
3	$Ca(NO_3)_2$ to maturity	61.4	14.9	13.3	.39	730	730	100	100	100	100	100	100	10	9	Very, very good	Very, very good
4	$Mg(NO_3)_2$ to maturity	62.0	13.4	11.6	.39	625	595	100	100	98	98	98	97	8	7	Fairly good	Fair
5	$NaNO_3$ to maturity	61.0	14.5	13.2	.45	650	655	99	100	99	98	98	96	9	7	Good	Good
6	KNO_3 to maturity	61.2	15.3	13.9	.45	730	675	100	100	99	98	99	98	10	9	Very, very good	Very good
7	NH_4Cl to maturity	59.6	18.2	16.7	.55	675	635	97	95	96	94	95	94	9	9	Good	Good
8	No salts to maturity	61.6	8.6	7.5	.51	470	500	90	90	90	89	90	89	6	6	Poor	Poor

[1] The writer desires to express thanks to C. B. Kress for the use of his equipment, and to Ludwig Reimers for the scoring of the samples listed herewith.
[2] All cultures grown in complete nutrient solution until the emergence of a first visible part of the head.
[3] In the scoring of bread for crust, 10 is the designation for "ideal crust" for bread purposes.
[4] Nine grades are used by General Mills laboratory in evaluating oven-spring, which are as follows: Very, very good; very good; good; fairly good; fair; fairly poor; poor; very poor; very, very poor. "Good" is considered as average quality.

did not ripen together, hence the length of the exposure of the plants to the various nitrate salts was not equal. This exposure varied about one week, but as an average it may be stated that each culture of the

Fig. 1. $Mg(NO_3)_2$ series headed out. Plants are approximately 4½ feet tall.

nitrate series was exposed to its respective salt for about seven-sixteenths of the total growing period. See Figures 1 and 2 for illustrations of growing conditions.

Milling and baking operations were performed according to the directions provided by General Mills for their experimental laboratories.

Inspection of the data and the figures bring several points into relief. They are:

(1) The exceptionally high quality of the loaf obtained from the $Ca(NO_3)_2$ treatment.

Fig. 2. NH_4NO_3 series headed out. Plants are approximately 6 feet tall.

(2) The markedly poorer quality (chiefly of grain and texture) of the NH_4NO_3 treatment.

(3) The order of the excellence of the bread is definite for three treatments out of the five nitrates, namely, $Ca(NO_3)_2$, first; KNO_3, second; and NH_4NO_3, last, i.e., fifth. The score for the $NaNO_3$ treatment appears to be a shade better than that of $Mg(NO_3)_2$. Essentially, the data confirm the validity of the deduction of previous experiments as to the order of excellence of three nitrate salts: $Ca(NO_3)_2$, KNO_3, $NaNO_3$.

(4) Ammonium salts supplied in aqueous culture media during the later growth stage of wheat resulted in higher protein values in grain than did nitrate salts, but the quality of the flour from cultures where the nitrogen was supplied to the growing wheat crop in the ammonium form was decidedly inferior in baking properties to that from cultures supplied with nitrogen in the nitrate form.

The photographs given are arranged to compare the various nitrate treatments with that of the complete nutrient solution, the latter being the standard for comparison of these tests. The protein content of the standard was 15.2% for the grain and 13.8% for the flour. It met the requirements for high bread scores so far as "quantity of protein" was concerned. The sample also met another requirement essential to high bread scores, namely, that the sap of the maturing crop was not deficient in inorganic elements when the proteins were being formed and translocated into the kernels. With nutrients available during the entire growth period, this standard sample contained more of the inorganic elements in the various tissues of the plants than was required as the irreducible minimum for the production obtained. As a consequence, a salt solution of considerable concentration bathed the protein and starch molecules during their syntheses and translocation into the grain-forming tissue. Both Table I and the photographs shown as Figures 3, 4, 5, and 6 bear witness that the standard ranked fairly high in the recognized elements of quality in bread.

High as the standard loaf ranks in quality, it is definitely exceeded in all points by the loaf obtained from the $Ca(NO_3)_2$ treatment. (See Figure 4, and Table I.) The protein contents of the two samples were practically alike, and their effect on bread score, even though the standard was actually 0.5% higher, must be considered as being approximately equal. The greater excellence of the $Ca(NO_3)_2$ sample apparently can only be accounted for by the effect which calcium had on the quality of the protein. The data suggest that the greater the proportion of calcium and nitrogen to other inorganic elements in the sap of the plant during the latter growth stage, the better is the quality of the protein and the higher are the bread scores of high-protein wheat. No differ-

ences occurred in the scores obtained by the differential treatment, i.e., the baking by the basic method compared with the stimulated one involving the addition of diatase. Whether this constancy in the various elements that make up the score of the $Ca(NO_3)_2$ sample is the property of a perfect loaf and obtainable only in wheats where the cultural con-

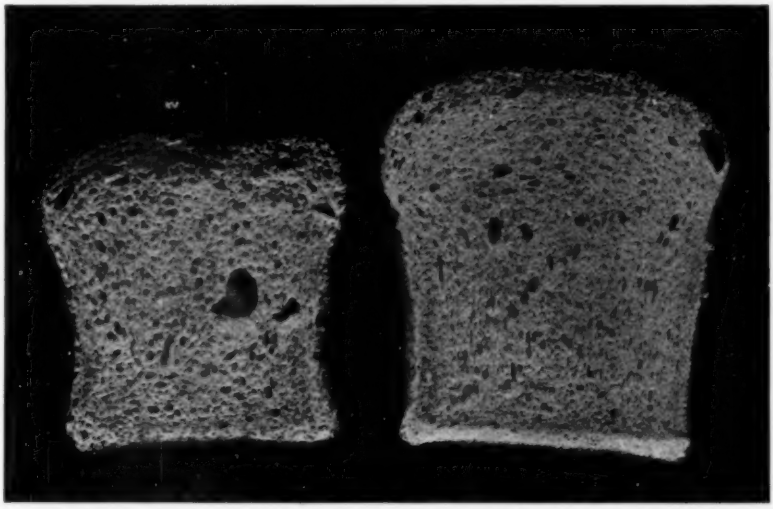

Fig. 3. Left (Sample No. 8, Table 1). No salts during the latter growth stage. Right (Sample No. 1, Table I—control). Complete nutrient solution during entire growth period.

ditions are such that calcium is the only cation which can be absorbed during the latter growth stage of the plant, requires further experimentation to give answer. That such may be the case appears as not improbable from a consideration of the effect which the arrangement of molecules and molecular aggregates has on the structural strength of materials.

A matter that has long challenged the inquisition of students of wheat culture has been the cause of the excellence of northern hard spring wheat. Due to the geological origin of the soils and the climatic features prevailing there, the conditions under which these wheats are grown appear to provide relatively more nitrogen and calcium to the growing crops during their latter growth phases and less nitrogen during the early growth periods, than is the case of wheat culture in milder climates. A region with mild climate and an abundance of rainfall would, on the whole, have a lower calcium content in the soil solution than would be true of a region with less rainfall. In case of nitrogen, high rainfall would usually be conducive to the accumulation of more organic residue in the soil than there would be in the case of a low rainfall. However, it must be remembered that in a study attempting to

explain the character of wheat by that of the region in which it is grown, it is necessary always to evaluate the absorptive properties of varieties; for wheats vary markedly in their ability to absorb nutrients from the soil. Thus the presence of a large supply of available calcium or nitro-

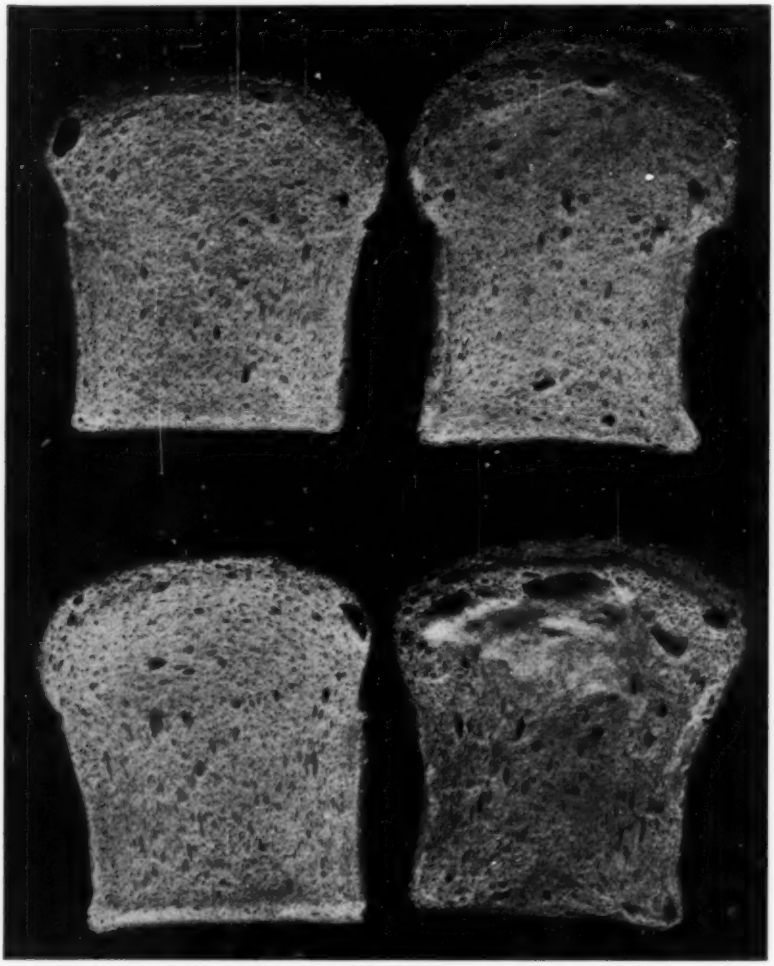

Fig. 4. Upper left (Sample No. 1, Table I—control). Complete nutrient solution entire growth period. Upper right (Sample No. 3, Table I). $Ca(NO_3)_2$ *only* during latter growth period. Lower left (Sample No. 1, Table I—control). Complete nutrient solution entire growth period. Lower right (Sample No. 2, Table I). NH_4NO_3 *only* during latter growth period.

gen in the soil during the latter growth phase of the plants is not evidence *per se* that the grain produced will yield high bread scores. Differences in bread scores among varieties exposed to the same cultural conditions will probably, in the final analysis, be explained by the differ-

ences in the absorptive capacities of the varieties for specific elements.

As shown in Table I and illustrated in Figure 6, the bread score for the KNO_3 treatment excelled that of the standard. Cultural conditions that restricted the absorptive capacity of the growing wheat crop to the intake of potassium and nitrogen during its latter growth stage were more beneficial to quality of protein than was the case where several

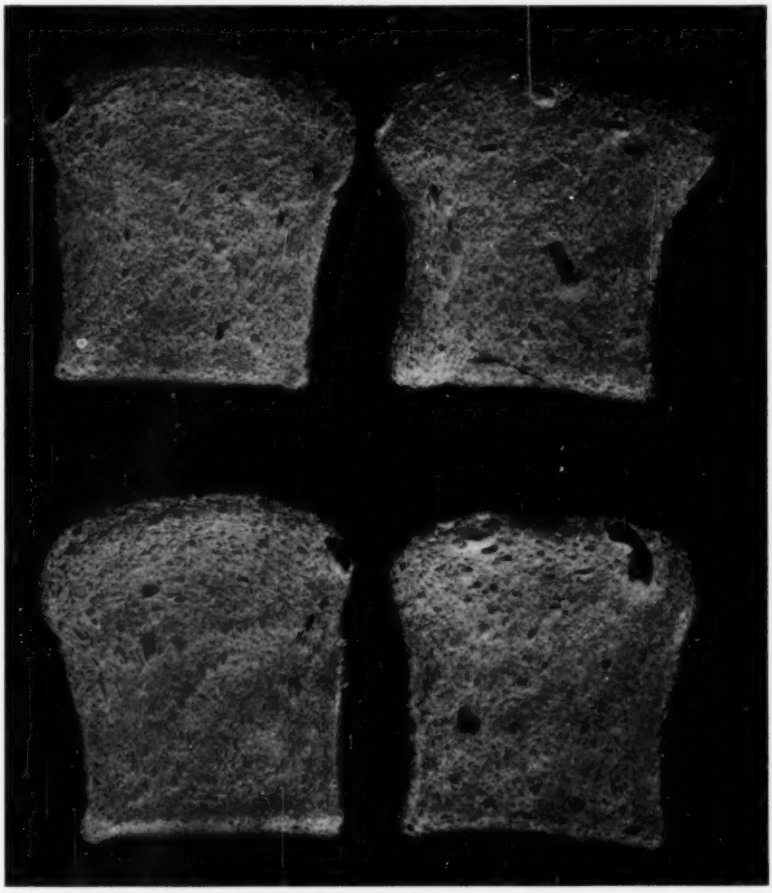

Fig. 5. Upper left (Sample No. 1, Table I—control). Complete nutrient solution entire growth period. Upper right (Sample No. 4, Table I). $Mg(NO_3)_2$ *only* during latter growth period. Lower left (Sample No. 1, Table I—control). Complete nutrient solution entire growth period. Lower right (Sample No. 5, Table I). $NaNO_3$ *only* during latter growth period.

salts were available supplying three or more different cations. From the data so far obtained, it may be assumed, however, that a mixture of KNO_3 and $Ca(NO_3)_2$ would be more beneficial to quality of protein than a pure solution of KNO_3, but the addition of any cation other than calcium to the KNO_3 solution would presumbaly result in a lowering of

the bread scores. The KNO_3 score differed from that of $Ca(NO_3)_2$ in that the loaf suffered changes with the stimulated baking procedure and apparently the decrease in volume resulted from a dough structure less strong than that exhibited by the $Ca(NO_3)_2$ treatment. As to the nature of the elements of dough structure in the various treatments, no

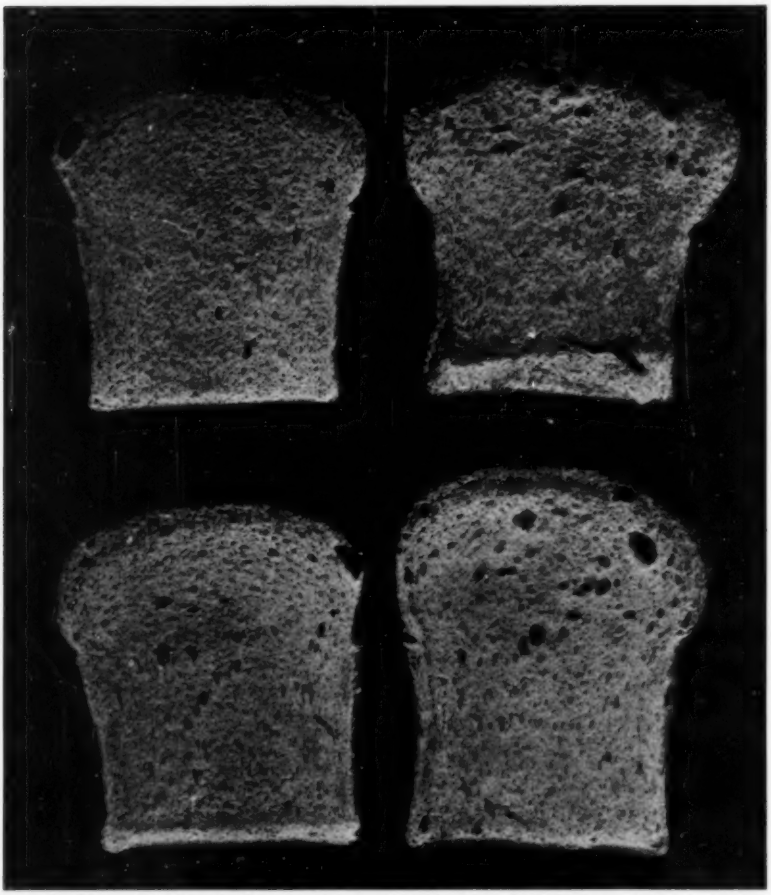

Fig. 6. Upper left (Sample No. 1, Table I—control). Complete nutrient solution entire growth period. Upper right (Sample No. 7, Table I). NH_4Cl *only* during latter growth period. Lower left (Sample No. 1, Table I—control). Complete nutrient solution entire growth period. Lower right (Sample No. 6, Table I). KNO_3 *only* during latter growth period.

worth-while exposition can be given at this time. The explanation of the differences presumably must await the results of study that will reveal or somehow clarify the physical constitution of molecular aggregates or masses concerned in the various flours.

The $Mg(NO_3)_2$ and the $NaNO_3$ treatments (see Figure 5) produced loaves which were lower in their respective scores than was the

standard loaf. These two treatments can be interpreted as having provided cultural conditions that precluded the growing wheat crops from absorbing calcium or potassium during their latter growth stage. The data do not warrant a statement as to which of the two elements (magnesium or sodium) was more harmful to quality, because the two samples were not sufficiently comparable in protein content. Data from other experiments, however, appear to indicate that magnesium is to be placed below sodium in its effect on quality in protein. This deduction can also be inferred from the bread score of the standard loaf, for the complete nutrient solution contained magnesium and no sodium, and the inferior bread score of this loaf as compared with that produced by $Ca(NO_3)_2$ and KNO_3 was presumably then, in part, due to the magnesium ion. It is, of course, not inferred thereby that the anions are without effect on the properties of bread.

NH_4NO_3 treatments ranked lowest in bread scores. This treatment was essentially a cultural condition which supplied large amounts of nitrogen and none of the mineral cations normally resident in fertile soils to the growing wheat crop during the latter growth phase. The failure to obtain high-quality bread from wheat so markedly high in protein appears to prove that those cations normally present in fertile soils play an important role in determining quality in protein. The NH_4NO_3 treatment was the only one which produced an appreciable increase in volume by the test of stimulation, but the large cavities in the loaf (Figure 4) are suggestive that its structure was near collapse. In order that a mass of dough which is confined in a pan may retain its original shape when the gas pressure within, which has created it, is released by baking, it is necessary that the structure be uniformly strong in all directions of its cellular constitution. It appears this was not the case with the NH_4NO_3 treatment as the loaf had the appearance of interior disintegration of its cellular structure, tending to cause collapse, but that this was precluded by the rigidity of the outer walls. The good oven spring obtained in the loaf appears to indicate that strength of wall operated somewhat independently of the interior structure of the mass.

The data on the NH_4CL treatment will be more fully discussed in a paper on the effect of the chlorides of these five cations. Since this treatment produced wheat markedly high in protein, it must be classified with the nitrate series as far as the comparison of effect of salts in the plant saps on the character of high-protein flour is concerned. The bread score of this loaf was low. Grain, texture, and color were decidedly inferior to any of the nitrate treatments, save that of NH_4NO_3. These characteristics are illustrated in Figure 6.

A comparison of the bread score of culture No. 8, which was exposed during its latter growth stage to water devoid of salts, with those of any of the nitrate treatments, leads to the conclusion that high-quality bread cannot be obtained if the culture medium becomes depleted of nitrate when the crop has attained to a growth stage indicated by the emergence of the first visible portion of the head. Because quality in bread is markedly affected by variation in the quantity of protein of the grain, it follows that too early depletion of nitrogen in the soil lowers the bread scores. If the depletion of nitrogen is likewise accompanied by the virtual depletion of cations, quality in bread suffers additional loss. Many soils cropped to wheat become practically depleted of nitrates before any of the nutritive cations are equally reduced. Because of the greater absorptive capacity of wheat for nitrogen than for other elements, it follows that the nutritive anions are usually depleted before the cations, and that the cultural conditions typified by culture No. 8 rarely, if ever, occur in land considered as suitable for wheat production. It is believed the bread score of this culture is about as low as this variety can ever attain. (See Figure 3.)

The fact that bread scores vary with the nature of the cation used to supply nitrogen, is evidence that quality in bread is in part controlled by other nutritional factors than those that determine the quantity of protein in grain. The absorption of nitrates cannot be considered independently of the absorption of cations, and, while wheat may possess some selective powers for specific elements, nevertheless its composition is known to vary more or less with the character of its culture medium. It appears from the date here given that quality in protein is markedly affected by the mineral nutrition of the wheat plants. It is affected by the concentration of the culture medium, as expressed by the results of the extreme conditions of no salts on the one hand, and ample quantities of nutritive salts on the other hand. It is also affected by the character of the salts, as manifested by the differences in baking scores obtained from nitrates supplied by five different cations.

DETERMINATION OF SPROUT DAMAGE IN WHEAT AND RYE BY MEANS OF THE DIPPING REFRACTOMETER [1]

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The usual commercial method of determining the sprout damage in grain is to count the percentage of sprouted kernels. However, since these kernels may be present in various stages of development and thus possess varying activity, it can easily be seen that this method cannot be especially reliable. A disadvantage is that it is very difficult to set a definite limit between kernels which should be considered sprouted and those which should be considered sound. It often happens that kernels which are intermediate in this respect and consequently are difficult to assign to one or the other class constitute a relatively large proportion of the entire sample.

A considerably more accurate measure of the sprout damage can be obtained by means of chemical methods. Such methods have long been available and have found some application in mill laboratories. In the grain trade, however, these chemical methods have not as yet been put to practical use, the primary reason being that the more generally known methods are time-consuming and difficult to carry out.

Every cereal chemist recognizes that the principal reason why sprouted grain is not suitable for milling purposes is that its enzyme content is too high. The changes in chemical composition undergone by grain during sprouting are of minor importance in comparison with the physiological changes resulting from the increase in enzymic activity. The enzymes that have the greatest influence in this case are the starch-splitting enzymes or diastases. Also the proteolytic or protein-splitting enzymes may be of great importance in certain cases. In determining sprout damage in grain, however, it is sufficient to determine the activity of the diastases.

It is recognized that the influence of the diastases on the properties of flour may be either favorable or unfavorable. A certain diastase content is desirable in flours used for baking purposes. The sugar preexisting in flour occurs in too low a concentration to nurture the yeast for any considerable length of time. Through the action of the di-

[1] Translated by Clinton L. Brooke, Pillsbury Flour Mills Company, Minneapolis, Minn.

astases, however, a new supply of sugar is made available for fermentation, satisfying the food requirements of the yeast. The diastatic activity must not be too high, else disturbing conditions will arise. This is especially true during the baking process.

A normal wheat-flour dough contains about 45% water. The 55% of dry material consists of approximately 45% starch, 6% protein, and 4% of other constituents. The greater part of the water is bound as swelling water by the two colloidal substances starch and protein. The amount of water taken up by the protein in swelling is very large—usually about twice the weight of the protein. Starch, on the other hand, binds only about its own weight of water. During the baking process a change occurs in this respect. The protein gel coagulates and thereby loses its capacity of holding water in combination, while the starch gelatinizes and its capacity to bind water is increased. The free water in the dough, together with the water set free upon coagulation of the protein, is absorbed by the starch during gelatinization. In order that the best possible bread shall be produced, it is essential that the amount of water available for gelatinization be neither too much nor too little. If the amount of water is so great that the starch cannot bind it all, the interior of the baked loaf becomes moist and gummy. In such cases the loaf is low in volume and water streaks and tears occur in the crumb. If insufficient water is present, not all the starch can gelatinize.

Through the well-known experiments of Katz we know that the principal reason why bread soon loses its fresh flavor and other desirable characteristics is that changes occur in the gelatinized starch. The gelatinization of starch, like so many other colloidal phenomena, is a reversible reaction. If starch paste of the concentration present in ordinary bread is kept at room temperature for some time, a gradual precipitation of amorphous starch takes place, with simultaneous liberation of water. The same phenomenon occurs in bread during storage. The water set free is partly absorbed by the coagulated protein gel, which swells and becomes tough, imparting to the bread the characteristic properties of stale bread. If the starch is completely gelatinized during baking, a longer time is required for the separation of amorphous starch than when gelatinization is incomplete on account of insufficient water and the solid phase of starch has thus been present in the system throughout the process.

The progress of starch gelatinization during baking is influenced above all by the quality and quantity of the starch and protein, but the diastatic power of the flour also plays a very important part. If the diastatic power is too low the bread often dries out and soon loses its fresh flavor; if too high, the loaf is flat and doughy. During baking the high concentration of diastase is responsible for an extensive hydrolysis

of starch into sugars and dextrins, thus reducing the amount of gelatinizable starch. The starch remaining at the onset of gelatinization is in such a case not in condition to bind all the freed water, with the result that the bread becomes doughy and of little value.

Only when the diastatic activity is properly adjusted in relation to the quality and quantity of proteins and starch can optimum results be obtained.

The diastatic power of flour is, however, of significance not only when flour is to be used in bread baking, but also when it is to be used in making pancakes,[2] gravy, and other household products. Excessive diastase is especially undesirable in baking the pancake. The limit here lies much lower than in bread flours.

As mentioned at the beginning of this article, an increase in proteolytic enzymes occurs during sprouting. The ability of the dough to retain the carbon dioxide formed by fermentation is dependent primarily upon the quantity and quality of the proteins. Since the effect of the proteolytic enzymes is to split the proteins into simpler compounds, their action obviously will affect the consistency and gas-retaining capacity of the dough. The changes caused by the proteolytic enzymes, however, proceed much more slowly than those caused by the diastases. Consequently the changes undergone by the proteins during the fermentation and baking processes are not of the same order of magnitude as those brought about by the diastases. Frequently the changes effected by the proteolytic enzymes during fermentation and baking are so slight that they can be demonstrated only with difficulty.

The alteration of the proteins during the actual sprouting process is, however, of a certain importance, especially when sprout damage is evidenced in such manner that a large proportion of the kernels show signs of sprouting—in other words, when the grain is generally sprout damaged. Two samples of the same wheat having the same high diastatic activity may produce flours of widely different character if in one case the high diastatic activity is due to the presence of a comparatively small number of kernels in an advanced stage of sprouting, and in the other case to sprout damage in a large proportion of the kernels. In the latter instance the proteins, especially those of soft wheat, are frequently so altered that the gas-retaining capacity of the dough is considerably reduced.

Since the effect of the diastases in the baking process is many times greater than that of the proteolytic enzymes, and moreover since it may be assumed that the diastatic and proteolytic enzymes increase more or less concurrently during sprouting, there is reason to believe that di-

[2] This refers to the so-called "oven-pancakes" made with flour, sugar, eggs, and milk. The ingredients are mixed and allowed to stand one hour, then beaten, placed in a frying pan, and baked in the oven.—*Translator.*

astatic activity is a comparatively reliable measure of sprout damage, especially when the suitability of grain for milling purposes is concerned.

It should be remarked here that the method by which the diastatic activity is determined is of considerable importance.

Before entering into a description of the method for determination of diastatic activity that has been in use at Saltsjökvarn for more than 20 years, I shall briefly survey the principles that in my estimation are of decisive importance for a method that aims to measure the extent of sprout damage.

Nearly 50 years ago Bourquelot advanced the theory that the diastases in grain consist of a mixture of two or more enzymes. This theory, which soon was supported by the investigations of Brown and Morris and others, has quite recently been confirmed by the work of Erik Ohlsson,[3] who has shown that both types of enzymes hydrolyze starch and thus are to be regarded as amylases. They may be differentiated, however, by means of their degradation products. One type is responsible chiefly for the formation of maltose and therefore is termed saccharogenase. The other type brings about the formation of degradation products among which dextrin predominates, and accordingly is called dextrinogenase. These correspond to the terms translocation and secretion diastase found in the older literature.

The optimum temperature for the activity of saccharogenase lies lower than that for dextrinogenase. The former has, moreover, considerably lower stability at high temperatures. Since in different flour samples not only the total diastase content but also the relation between the different types of diastase may vary, different comparative values will be obtained according to the temperature at which the comparison is made. The establishment of an accurate working temperature is therefore of the highest importance. The temperature selected is wholly dependent upon the aim of the experiment. If the aim is to determine the action of the diastases in fermentation, one should, like Rumsey, Kent-Jones, Ritter, and others, choose a temperature corresponding to the normal temperature of dough fermentation. If one wishes to obtain a measure of the diastatic activity during the baking process, the temperature selected should correspond as closely as possible with that at which starch hydrolysis is effected in baking. Undoubtedly the most appropriate procedure would be to let the temperature follow a curve which as closely as possible corresponds with actual practice.

Another matter of great importance is the method of procedure in determining the magnitude of the changes. If the problem is to determine the action of the diastases in fermentation, the sugar determination would obviously be the most appropriate. If, on the other hand, the

[3] Ohlsson, Erik. Sur l'existence de deux ferments amylolytiques dans la diastase du malt. Société de biologie, Comptes Rendus. 87: 1183–4 (1922). (Chemical Abstracts 17: 1648.)

purpose is to determine the effect of diastatic action during the baking process, the determination should include the total products of hydrolysis, which does not correspond to sugar formation.

In the case in hand, *i.e.*, the determination of sprout damage, the basic principle is that the autolysis should be performed at a relatively high temperature and the total products of starch hydrolysis then determined in some convenient manner. It is this approach to the problem that underlies the method described in the following:

Method

Apparatus

1. Analytical balance.
2. Test tubes. Length 180 mm., inside diam. 21 mm., thickness of wall about 1.2 mm., wt. 35–40 gms.
3. Glass stirring rods (tubing fused shut at one end). Length about 300 mm., diam. 7 mm., wt. 15 gms.
4. Water thermostat. Diam. 500 mm. Designed to accommodate 10 test tubes. Provided with stirrer and cover. The test-tube holder is circular in form. 500 watt heating element with resistance. Thermometer graduated to 0.1° C. A satisfactory thermostat is shown in Figure 1.

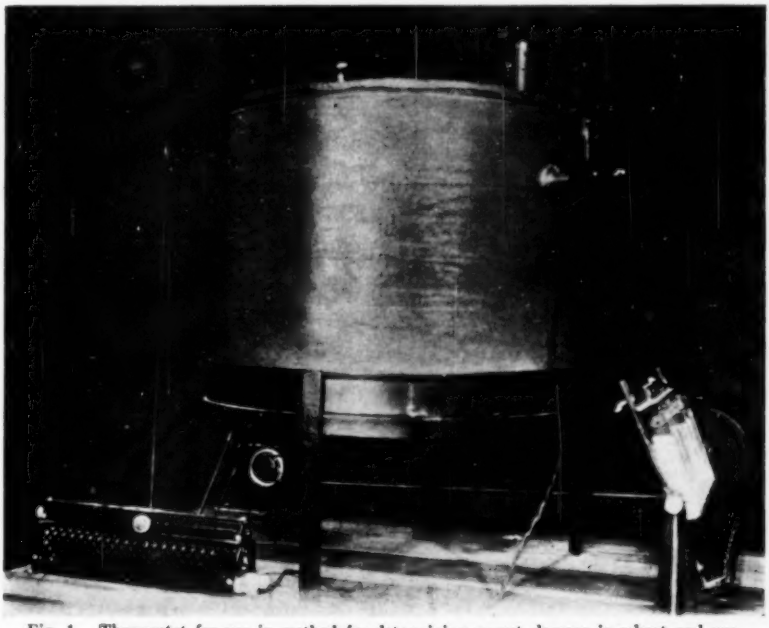

Fig. 1. Thermostat for use in method for determining sprout damage in wheat and rye.

5. Shaking machine for 10 test tubes.
6. Cooling bath with holder for 10 test tubes.
7. Dipping refractometer (Prism n_D 1.325–1.366) with bath, thermometer, and refractometer beakers.
8. Devices for accurate measurement of 2, 3, 20 and 25 cc. Automatic pipettes preferable.
9. Funnels and filter rack.

Procedure

1.25 gms. of flour is weighed and transferred quantitatively to a dry test tube, 3 cc. of distilled water at room temperature is added, and the flour and water are mixed into a smooth paste by means of a glass stirring rod. Lump formation may be avoided by first stirring in the flour at the top and gradually working down to the bottom of the tube. The tubes are placed in a test tube rack until five samples have been prepared. The suspensions are stirred again just before placing in the thermostat, which should be held at exactly 62° C. Under no circumstances should the tubes be disturbed or the suspensions stirred during heating.

Autolysis is interrupted after exactly 10 minutes by transferring the tubes to the cooling bath. The time should be controlled by a stop-watch. During autolysis the temperature of the water thermostat should not vary more than 0.1° C.

After 4 minutes cooling, during which time the suspension should not be disturbed, 2 cc. of distilled water is stirred into the suspension. Further dilution is now accomplished by the addition of 20 cc. of distilled water, whereupon the stirring rod is removed and the tube shaken thoroughly.

The tubes are now allowed to stand for 30 minutes in order to facilitate filtration through the settling out of suspended material. Filter through folded filters (Munktell's No. 3, 11 cm. diam.).

The filtrate is caught in refractometer beakers, the first 4 cc. being poured back to ensure a clear filtrate. Filtration is continued until the beaker is filled to the ground ring (about 7–8 cc.).

The beakers are now inserted in the refractometer bath, which is held at 17.5° C., and as soon as the prism and the beakers have adjusted themselves to the temperature of the bath the scale is read to hundredths of a division.

In order to correct for the soluble substances preexisting in the flour, a blank determination is made as follows: Weigh 1.25 gms. of flour into a test tube, add 25 cc. distilled water, shake 15 minutes in the shaking machine, filter into a refractometer beaker, and read as above. The difference between the reading on the heated suspension and that on the blank, multiplied by 5, represents the amount of starch hydrolyzed during autolysis, expressed in percentage of the flour.

Wherever possible the blank determination should immediately follow that on the heated sample. Duplicates are run in all cases but the two samples should not be autolyzed simultaneously.

The final result is given with an accuracy of 0.1 unit.

In the 20 years this method has been in use at the cereal laboratory of Saltsjökvarn, over 50,000 determinations have been made. It can readily be seen that the method may be used not only for determining sprout damage in grain, but also for controlling the quality of the flour produced by the mill. Although it has not previously appeared advisable to publish the details of the method, we have never concealed the fact that we were making use of a chemical method for the determination of sprout damage. In past years we have made a great many determinations for state and private institutions.

Owing to the frequent occurrence of sprout damage in Sweden, the problem of the chemical determination of such damage has interested several of our mill chemists. In at least one case this has led to the development of a method which in principle is much like our own. I refer to the method of Sven Hagberg.

During the past year yet another refractometric method has appeared in Sweden, the method of Dr. Lindberg of Svalöf. For the sake of completeness I will include a brief mention of the origin of this method.

In trading in mill grains, sprouted grain usually commands a lower

price than sound. The price deduction is based on the percentage of sprouted kernels. In establishing the price, disputes have frequently arisen because of the difficulty of determining the extent of sprout damage through counting the sprouted kernels. Since members of the State Grain Commission knew that more reliable methods were available, although not generally known, the Commission decided in May, 1931, at the suggestion of Dr. Åkerman, to entrust the cereal laboratory at Svalöf with the task of investigating the matter and working out recommendations for a chemical method. The work was assigned to Dr. J. E. Lindberg, who in September, 1931, submitted a proposal for a chemical method, which in several particulars resembles those developed by Hagberg and myself. The points of similarity in the three methods are the following:

1. Diastatic activity is determined by autolysis of a flour-water suspension.
2. The temperature during autolysis is around 60° C.
3. The products of starch hydrolysis are determined by means of the dipping refractometer.

Differences occur in the amount of flour and the concentration of the suspension during autolysis and refraction, as well as in the method of inhibiting diastatic activity and in the deduction for the blank.

In the foregoing I have discussed only the determination of diastatic activity in wheat flour. Since rye flour as a rule has a considerably higher diastatic activity than wheat flour, the same treatment is not applicable in both cases. If the determination is to be made on rye flour, one must either shorten the time of autolysis or lower the temperature. We have chosen the former alternative, heating the rye flour suspension only 5 minutes instead of 10 minutes as with wheat flour.

When sprout damage in grain is to be determined, the grain must of course first be milled into flour. Experience has shown that best results are obtained with a flour of 0–50% extraction (Hungarian system).

In closing I wish to say a few words about the experimental error in the above method. When the determination is made on flour the mean error usually lies within 1%, but when the determination is made on grain a further error is introduced by variations in milling. This error is usually greater than that involved in the determination itself.

If any great degree of accuracy is to be anticipated in determinations on flour milled from grain samples, it is of prime importance that the sample taken for milling be not too small—several hundred grams should be the minimum.

AN AUTOMATIC SHORTOMETER [1]

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Two mechanical devices for measuring the breaking strength of cookie-cakes have been described by Davis.[3] Both provided two parallel rails to support the cake, and a bar or " striking member " which exerted the crushing force across the center of the cake. In one of the devices, Davis applied the force by pouring shot into a cylindrical cup mounted on a shaft which in turn was supported by the bar or striking member. In the second device the striking member was attached to one end of a lever on which a sliding weight was mounted.

In a personal communication Davis advised that the latter had not been used extensively; he also indicated an improvement of the former in which water was used instead of shot. Data were accumulated by him pertaining to the relative contribution to breaking strength or " shortness " of cakes that was made by various types of edible fats or shortening.

A similar instrument was constructed here several years ago for use in determining the breaking strength of cookies, and extensive measurements of shortness were made. It soon became apparent that a large variability might be anticipated in the instance of replicated measurements of a series of individual cookies baked from the same batch of dough. Whether or not these variations were due to actual differences in the cookies, or whether they represented in part the errors of the measurement itself was not evident at once. In all probability both factors were operative, in which event the perfection of the mechanical device would still entail a considerable number of replicate measurements in the instance of each set of samples. This, in turn, means that the instrument must be so designed as to permit of rapid operation in order to conserve the technician's time.

In redesigning the shortometer to increase the number of tests that could be made per unit of time, recourse was had to the degree of compression of a spring as an index of the breaking force applied.

[1] Paper No. 1234 Journal Series, Minnesota Agricultural Experiment Station.
[2] With the technical assistance of David Crowther and Christian Dane.
[3] Ind. Eng. Chem. 13, 797 (1921).

Such a system was conveniently supplied in an ordinary household spring "scale" constructed to weigh about 5 pounds. The cookie to be tested was laid on the two supporting rails bolted securely to the scale platform as shown at R in Figure 1. These rails were made of round iron rod

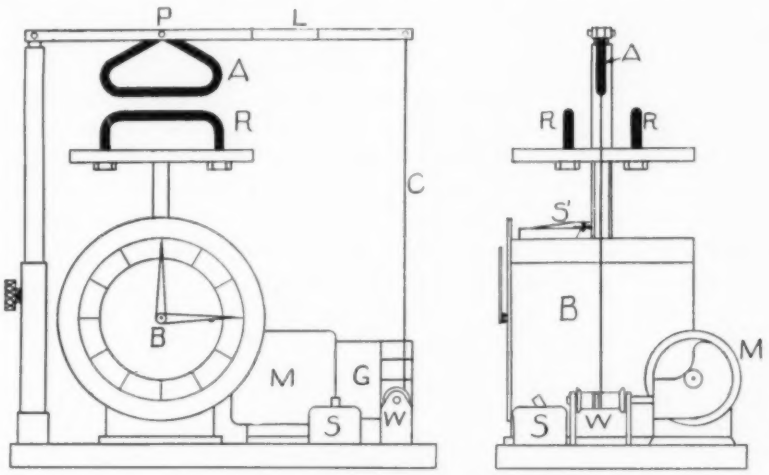


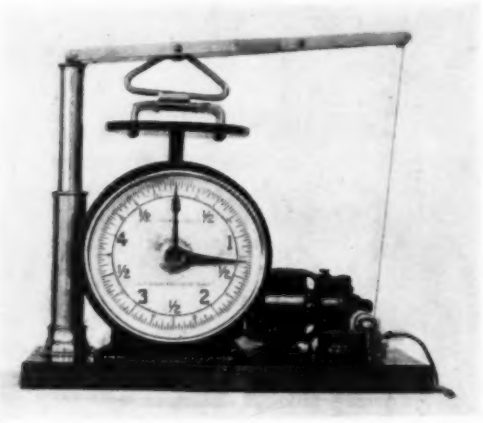
Fig. 1. Diagram of the automatic shortometer.

6.5 mm. in diameter, mounted parallel with their centers 40 mm. apart. The breaking force was applied through the striking member A, supported from the lever L by the pin P. This pin enabled the delta-shaped striking member to swing free in a plane parallel to that of the long axis of the rails R.

In the first stage of development of this shortometer the lever L was moved downward from the fulcrum F by pressure of the hand until it engaged the center of the cookie. Sufficient additional pressure was then applied to fracture the cookie. At the instant when the latter broke the platform would spring upward under the tension of the spring. A registering needle was provided with the balance which remained in the position occupied when the maximum force was applied at the instant that the cookie fractured. This facilitated reading the magnitude of the pressure equivalent to the breaking strength of the cookie.

The force required to compress the scale spring was determined by placing metric weights on the scale platform and noting the position of the needle on the dial. Weights were usually added in increments of 250 grams, the dial readings were noted, and a graph constructed for use in converting these dial readings into metric weight equivalents. Periodically these calibrations were repeated to ascertain whether or not any substantial change had occurred in the relative compressibility of the spring.

After a series of tests had been made in this manner, it appeared that difficulties were being encountered in uniformly applying the force requisite to fracture the test pieces. We accordingly elaborated on our original design by adding a motor *M* to apply this force. The motor shaft was connected to a speed-reducing gear, the low-speed gear in turn being attached to a shaft *W* 8 mm. in diameter which rotated at the rate of 20 revolutions per minute. The latter constituted a small windlass over which the cord *C* would wind when the shaft was rotated by the motor. Still later we found it possible to purchase small motors having a reducing gear built into the case of the motors. The slow speed shaft of the motor rotating 4.5 r.p.m. could then be attached to a simple windlass, as illustrated at the lower right of the photograph shown in Figure 2. This windlass was of such dimensions that the cord *C* was drawn downward at the rate of about 120 mm. per minute.



(Courtesy, Institute of American Meat Packers.)

Fig. 2. Photograph of the automatic shortometer.

With the cookie to be tested in position, the motor was started, and the windlass *W* caused to wind up the cord *C*, thus bringing the striking member *A* in contact with the center of the suspended biscuit. The force applied from this time forward was indicated on the dial of the household scale. At the instant of fracture of the cookie, the tension of the scale spring caused the platform to jerk suddenly upwards. A pin projecting from the scale platform support then forcefully struck the friction electric switch *S'*, forcing it open. This switch was in series with one of the electric power lines leading to the motor and the shaft of the latter immediately stopped rotating.

The maximum spring tension was noted on the dial of the scale, and the indicating needle then set back to zero. The cord was unwound

from the windlass by releasing a simple clutch on the shaft of the device. This made it possible to again raise the lever L high enough so that another cookie could be placed between A and R. A manually operated snap switch S was snapped "off," the switch at S' was closed and then by snapping switch S into the "on" position the mechanism could be set in motion again for the next test. All of these resetting features could be manipulated in a few seconds, and thus a series of a score or more of replicated tests could be conducted speedily and with precision.

As already indicated, such empirical tests proved to be somewhat variable at best, and to compensate for this variability numerous replicated tests were made. The average probable error of the means of 10 series of tests that were each replicated 20 times was 36.2 grams, when the average of the means was about 1500 grams, the average P.E. $\bar{x}$ being thus 2.41% of the average mean or $\bar{x}$.

Summary

An automatic shortometer is described which was designed to measure the breaking strength of cookies. It consists of a compression spring scale or "balance" provided with supports for the cookies. A striker member exerts force on the center of the cookie. This force is applied by a lever which is drawn downward by a cord, which, in turn, is being wound over a motor-operated windlass. At the instant that the cookie breaks, the entire moving system is stopped by opening the electric circuit through a friction switch. The maximum force can then be noted on the dial of the scale. The average probable error of the means of tests replicated 20 times was 2.41% of the average of the means.

VARIETAL AND OTHER VARIATIONS IN PEPTIZABILITY OF WHEAT FLOUR PROTEINS[1]

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The evaluation of flour for baking strength still remains a real problem to the cereal chemist. Correlational studies show a relationship between protein content and baking quality as measured by loaf volume. The degree of correlation obtained, however, between protein content and baking quality, while usually significant, is of such magnitude as to strongly indicate the presence of other factors. One of these factors is presumed to be protein or "gluten quality." Baking tests as a means of determining "gluten quality" have obvious disadvantages, and suggested physico-chemical methods, such as viscosity measurements, have not stood the test of critical experimentation. The peptization of flour proteins by different reagents has suggested a possible means of differentiating wheat proteins.

Gortner and his associates (1929, 1929a) have shown that solutions of electrolytes vary in their ability to peptize wheat proteins, and that proteins of different wheats vary in their resistance to peptizing agents.

Harris (1931, 1932) has made extensive studies on the relation of peptizability of flour proteins to baking quality. His data show a correlation between non-peptizable protein and baking quality.

Geddes and Goulden (1932) have also studied the peptization of wheat proteins and the relation to baking quality. They find no essential difference between peptizability of flour proteins milled from sound wheat, and from immature and frost damaged wheat. High negative correlations were also obtained between total protein and percentage of total protein peptized. Geddes and Goulden also state that "the basic baking procedure revealed no significant difference in the relative value of the peptized and non-peptized protein fractions for baking purposes."

The previous studies have given but little attention to varietal variation in peptizability, and to variation of the same variety when produced under different environments. The present paper deals particularly with varietal and environmental variation in peptizability of wheat proteins.

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Experimental

The flours used for this study were 75% patents prepared in an Allis experimental mill. For the 1930 crop, flour from 10 varieties of common wheat and 3 varieties of durum wheat from the variety plots at Fargo were used. Total protein and protein peptized by normal K_2SO_4 and normal $MgCl_2$ solutions were determined on these samples.

For the 1932 crop, six varieties of common wheat and two varieties of durum wheat from five different locations were used. Protein peptized by normal solutions of K_2SO_4, $MgCl_2$, and KBr was determined, and, in addition, the protein soluble in 70% ethyl alcohol. Baking tests were made on all flours by the basic A. A. C. C. procedure. The samples selected from the 1932 crop, therefore, made possible a study of both varietal and environmental factors.

Results from 1930 Crop

As stated previously, the flour in this case was prepared from wheats grown at Fargo. The common wheat varieties are divided for purpose of discussion into groups A and B. Group A consisted of wheats having fair to good baking quality, while group B consisted of four varieties which are *notably poor* in baking quality, namely, the varieties Marvel, Hurdsfield, Preston, and Progress. The data are shown in Table I.

TABLE I

VARIETAL VARIATION IN PROTEIN PEPTIZABILITY (1930 CROP)
(15% Moisture Basis)

Flour from Wheats Grown on Fargo Plots

Variety	Total protein in patent flour	Percent of total N soluble in normal K_2SO_4	Percent of total N soluble in normal $MgCl_2$
	P.ct.		
COMMON WHEATS			
Group A			
Marquis	13.4	11.5	19.8
Ceres	13.8	11.2	18.8
Reward	15.2	13.0	20.5
Reliance	11.7	10.4	18.1
Marquillo	14.3	12.5	21.0
Hope	13.0	12.0	20.3
Group B			
Marvel	16.1	12.1	19.0
Hurdsfield	15.6	12.4	20.3
Preston	14.1	12.7	20.4
Progress	15.5	11.6	19.3
DURUM WHEATS			
Mindum	12.6	13.3	22.1
Kubanka	13.2	11.8	21.3

Peptizability in normal K_2SO_4 solution. Considering the common wheats listed as group A, it will be noted that the varieties Marquis, Ceres, and Reliance are less easily peptized than the varieties Reward, Marquillo, and Hope. In group B, the variety Progress showed a low percentage of protein peptized. The other three poor quality varieties did not differ substantially in peptizability from those varieties of group A.

The durum wheats as a group did not show any significant variation in peptizability although the variety Mindum showed a higher percentage of proteins soluble in K_2SO_4 solution than any other variety.

Peptizability in normal $MgCl_2$ solution. In group A, the common wheats, Ceres and Reliance, showed a lower percentage of peptizable protein than the other four varieties. The poorer quality varieties of group B are not essentially different in peptizability than the better varieties of group A. The durum variety Mindum again showed the highest percentage of peptizable protein, but this percentage is not significantly higher than the percentage associated with the common wheats.

The results obtained from the wheats of the 1930 crop, therefore, do not indicate a wide varietal range in protein peptizability. Considering the two groups of common wheats, groups A and B, the rather small and inconsistent differences between varieties indicate that protein peptizability determinations would not be useful in predicting baking quality.

Results from the 1932 Crop

A more extensive study was made with wheats from the 1932 crop. Flour was prepared from wheats grown at Fargo, Dickinson, Langdon,

TABLE II

PROTEIN CONTENT (N × 5.7) OF PATENT FLOURS (1932 CROP)
(15% Moisture Basis)

Variety	Grown at: Fargo	Langdon	Edgeley	Dickinson	Williston	Average five locations
	P.ct.	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*
COMMON WHEATS						
Marquis	12.3	12.9	13.5	11.7	14.4	13.0
Ceres	12.5	13.3	12.8	11.9	13.6	12.8
Reward	14.0	15.4	13.6	12.9	14.8	14.1
Reliance	11.3	12.0	12.6	10.9	14.0	12.2
Marquillo	12.9	14.0	14.0	12.2	14.7	13.6
Hope	12.4	12.9	13.8	12.1	14.1	13.1
Marvel	14.6[1]					
Hurdsfield	12.9[1]					
Average	12.6	13.4	13.4	12.0	14.3	
DURUM WHEATS						
Mindum	11.4	12.7	13.4	11.6	15.1	12.8
Kubanka	11.7	13.7	15.1	10.8	15.1	13.3
Average	11.6	13.2	14.3	11.2	15.1	

[1] Not included in average.

Edgeley, and Williston, North Dakota. Six varieties of common wheats (Marquis, Ceres, Reward, Reliance, Marquillo, and Hope) and two varieties of durum wheat (Kubanka and Mindum) were used for this study. In addition, the varieties Marvel and Hurdsfield, grown on the plots at Fargo, were used. This selection gave six varieties of common wheat grown at five different locations for comparative purposes.

Since these wheats were grown under different environmental conditions, the total protein content of the patent flours showed some variation, and these data are given in Table II. The Williston samples averaged highest in protein content, the Dickinson flours were lowest in total protein content. A summary of the data with respect to the protein peptization studies is given in Tables III and IV. The data are averaged in Table III to show differences between varieties, and in Table IV to show differences due to environment.

TABLE III

VARIETAL VARIATION IN PROTEIN PEPTIZABILITY (1932 CROP)

Average of wheats from 5 locations[1]

Variety	Average percent total N soluble in N K_2SO_4	Average percent total N soluble in N $MgCl_2$	Average percent total N soluble in N KBr	Average percent total N soluble in 70% alcohol
COMMON WHEATS				
Marquis	12.1	26.6	31.1	51.0
Ceres	11.3	25.5	29.4	53.1
Reward	12.4	26.3	30.3	51.8
Reliance	12.4	27.1	30.9	54.5
Marquillo	13.2	27.7	31.9	51.9
Hope	12.3	26.8	30.6	51.9
Marvel[2]	12.4	27.3	30.2	54.3
Hurdsfield[2]	13.3	26.5	32.2	55.8
Mindum	13.7	29.7	36.1	53.4
Kubanka	13.1	29.2	34.9	50.4

[1] Data on 75% patent flour from wheats grown at Fargo, Langdon, Edgeley, Dickinson, and Williston.

[2] Grown only at Fargo.

TABLE IV

REGIONAL VARIATION IN PROTEIN PEPTIZABILITY (1932 CROP)

Location	Average total protein (N × 5.7) in patent flour	Average percent N soluble in N K_2SO_4	Average percent total N soluble in N $MgCl_2$	Average percent total N soluble in N KBr	Average percent total N soluble in 70% alcohol
	P.ct.				
COMMON WHEATS[1]					
Fargo	12.6	12.3	26.2	30.1	53.0
Langdon	13.4	12.0	25.8	29.9	52.7
Edgeley	13.4	12.3	26.9	31.3	52.8
Dickinson	12.0	13.0	28.4	32.3	51.9
Williston	14.3	11.8	26.0	30.0	51.5

[1] Average of six varieties.

Varietal variations. The rank of the common wheat varieties as to total average protein content was as follows: Reward, Marquillo, Hope, Marquis, Ceres, and Reliance, in the order named (Table II). The variety Reward averaged the highest protein content, 14.1%, compared with 12.2% for the variety Reliance. The variety Mindum averaged 12.8% protein as compared with 13.3% for the variety Kubanka.

Protein peptized by normal K_2SO_4 solution. (Table III.) As a group, the durum wheat flours averaged somewhat higher in peptizable proteins than the common wheats. The variety Marquillo showed 13.2% protein soluble in K_2SO_4 solution as compared with 13.1% for Kubanka. Of the six common wheat varieties, Ceres showed the lowest peptizability and Marquillo the highest. The difference, however, is not great. For the five locations, Ceres showed consistently low peptizability, while the variety Marquillo, with one exception (Langdon), gave consistently high results.

Protein peptized by normal $MgCl_2$ solution. (Table III.) The two durum varieties showed a higher percent of peptizable protein than any of the varieties of common wheats studied. In the case of the common wheats, the variety Ceres again showed the lowest peptizability and the variety Marquillo the highest. The differences between varieties and types, however, were relatively small. The variety Ceres averaged lower in peptizable protein than the other varieties, but the variety was not consistently low in this respect. At Langdon the variety Ceres showed 25.3% of total protein peptized, while the variety Reward showed 25.1%. The variety Marquillo averaged the highest, but was not consistently high. Of the common wheats grown at Fargo, the variety Marquis showed the highest percentage of peptizable protein, while within the same class of wheats when grown at Langdon, the variety Reliance showed the highest percentage of peptizable protein.

Protein peptized by normal KBr solution. (Table III.) With KBr a greater difference in protein peptizability was noted between the common and durum varieties. While the spread between the common wheat varieties was relatively small, it is interesting to note that the variety Ceres was again the least peptized, while the variety Marquillo showed the greatest amount of peptization. The variety Ceres was consistently low, but the variety Marquis exceeded the variety Marquillo at both Fargo and Dickinson.

Protein soluble in 70% ethyl alcohol. No consistent difference between common and durum wheats is indicated by the data in Table III. The varieties Reliance and Ceres, of the common wheats, produced the highest percentage of protein-soluble-in-alcohol. The variety Marquis produced the lowest percentage of alcohol-soluble-protein. The differ-

ences between varieties in this case, however, are not as consistent as with solutions of electrolytes.

With solutions of electrolytes, Ceres wheat rather consistently shows the lowest peptizability, and Marquillo the highest; but, with 70% alcohol, Ceres averages higher in percentage of peptized protein. The Mindum variety very consistently shows a higher peptizability than Kubanka, with both electrolytes and 70% alcohol. The variations between different varieties, however, are small particularly when considered in connection with variability due to environment.

Environmental Variation in Peptizability

In Table IV the averages show the regional or environmental variation in protein peptizability. Flours milled from wheats grown at Dickinson show the highest average peptizability with all three electrolytes, while flours from wheats grown at Williston show the lowest average for peptizable protein both for electrolytes and 70% alcohol.

With normal K_2SO_4 solution, there is a striking relationship between total protein and peptizable protein. The peptizable protein apparently varies inversely as the total protein content. The average results with $MgCl_2$ and KBr solutions show the same tendency but the relationship is not as apparent as with K_2SO_4. With 70% alcohol, the wheat grown in western North Dakota (Dickinson and Williston) showed a lower percentage of peptizable protein than wheat grown at Fargo, Langdon, or Edgeley.

The data indicate that variations due to environment are as great as varietal variations. The average standard deviations for the varietal and environmental variations were calculated and found to be of practically the same magnitude. The fact that environmental variation is as large as the varietal variation suggests that variation in protein peptizability is of doubtful value as a means of classifying wheat varieties.

Relation Between Total Protein Content and Peptizability

In Table V are shown correlation coefficients calculated between total protein content and the different peptized fractions for common wheats only. All coefficients are negative, but only three are greater than the probable error. The correlation coefficients indicate that peptizability of the proteins varies inversely as the total protein content. This tendency is greatest in the alcohol soluble fraction, and least in the case of the KBr soluble fraction. Geddes and Goulden (1932) have found the same tendency. Apparently seasonal or climatic conditions, which produce wheat of high protein content, also tend to produce a protein which is less peptizable. Low rainfall and high temperatures produce wheat of high protein content, and apparently these same conditions have a tendency to reduce solubility or peptizability of the protein constituent.

TABLE V

CORRELATION BETWEEN TOTAL N AND PEPTIZABLE N

	Number of samples[1]	Coefficient of correlation	Probable error
Total N *vs.* N soluble in 70% alcohol	32	−0.240	±0.112
Total N *vs.* N soluble in N K_2SO_4	32	−0.180	±0.115
Total N *vs.* N soluble in N $MgCl_2$	32	−0.129	±0.117
Total N *vs.* N soluble in N KBr	32	−0.026	±0.119

[1] Common wheats only.

Rust injury apparently has some effect on peptizability in normal K_2SO_4 solution. A comparison of Marquis and Mindum wheat grown at Langdon and Fargo in 1930, furnishes some interesting data on this point. Marquis was severely rusted at Langdon, but rust injury at Fargo was small. The Marquis produced at Langdon showed 14.2% of the total N soluble in K_2SO_4, while the Marquis from Fargo showed only 10.3% peptized by K_2SO_4. Mindum, a durum variety, and more resistant to rust than Marquis, under same conditions showed 12.7% of total protein peptized by K_2SO_4 when grown at Langdon and 11.8% at Fargo. While the total protein content averaged higher at Fargo, this could hardly account for the difference of almost 4% in peptizability of Marquis protein from the two locations.

Relation Between Protein Peptizability and Baking Quality

Loaf volume is used as a measure of baking quality. Mangels and Stoa (1931) have shown that loaf volume cannot be used as a sole criterion of baking quality, but it is a measurable quantity and is therefore used in this comparison. In Table VI are shown correlation co-

TABLE VI

CORRELATION BETWEEN LOAF VOLUME AND PEPTIZED PROTEIN

	Number of samples[1]	Coefficient of correlation	Probable error
Loaf volume *vs.* total protein (N × 5.7)	32	+0.298	±0.108
Loaf volume *vs.* N soluble in 70% alcohol	32	−0.130	±0.117
Loaf volume *vs.* N soluble in N K_2SO_4	32	−0.055	±0.118
Loaf volume *vs.* N soluble in N $MgCl_2$	32	+0.062	±0.118
Loaf volume *vs.* N soluble in N KBr	32	+0.029	±0.119

[1] Common wheats only.

efficients for common wheats only. The coefficient of 0.298 for the loaf volume and total protein content is about what would be expected from a mixture of varieties. The other coefficients are small and with one

exception are less than the probable error. The coefficient between alcohol soluble protein and loaf volume is -0.130 ± 0.117. This would indicate that baking quality as measured by loaf volume will vary inversely as the percent of protein peptized by 70% alcohol.

Discussion

The variation in peptizability of proteins of different types and varieties of wheat is not as great as would be expected considering the difference in quality of the wheats used for comparison. For the 1930 wheats (Table I) there is, for example, no consistent variation between the common wheats in group A and the poor quality wheats in group B. The protein of the varieties Marvel and Hurdsfield, grown at Fargo in 1932 (Table III), does not differ greatly in peptizability from other varieties. These two varieties are of very poor baking quality.

While durum wheats as a class show a greater percentage of peptizable protein, the variation is not consistent. With the common wheats protein peptizability apparently tends to vary inversely with baking quality, but in only one case does the correlation coefficient approach the horizon of significance. Variation in protein peptizability due to environment, is equal in magnitude to the varietal variation. The data presented indicate that peptizability of proteins can hardly be used, therefore, as a basis for classifying wheat varieties, or for selecting wheats for quality.

To what extent are variations in baking quality due to "gluten quality"? The term "gluten quality" has been used rather loosely to explain differences in quality not readily attributable to other factors. Granting that a "gluten quality" factor exists, the writer is of the opinion that "gluten quality" has often been used to explain differences which are actually due to saccharogenesis, and possibly to the effect of lipoids or fatty materials on the colloidal properties of doughs. The protein constituent of wheat and flour may actually be less variable in constitution and properties than the chemist has presumed it to be. Recent advances in the technology of flour manufacture in this country have been concerned primarily in controlling saccharogenesis and the gas producing power of the flour. The influence of lipoids and fatty materials on collloidal properties of doughs (usually ascribed to the protein constituent) is yet to be determined. Some variations noted in physiochemical measurement of dough properties may be due to substances associated with protein, rather than the protein constituent.

While apparently, as stated previously, protein peptizability can not be used for classifying wheats as to quality, further study of the peptization phenomenon may throw some light on the basic cause of variation in quality.

Summary

Protein peptized by normal solutions of K_2SO_4, $MgCl_2$, and KBr and 70% alcohol was determined on a series of experimentally milled patent flours.

Varietal variation in peptizability is not of large magnitude.

Variation in peptizability due to environment is of as great magnitude as the varietal variation.

Protein peptizability tends to vary inversely as the total protein content.

There is a slight tendency for baking quality to vary inversely as protein peptizability, but only one correlation coefficient approaches the horizon of significance.

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SOME FACTORS INVOLVED IN DAMAGE TO WHEAT QUALITY [1]

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Previous studies by Swanson and Fenton (1932) have shown that a high moisture content is the fundamental cause of damage to farm stored wheat. A relatively high moisture content will accelerate respiration in the grain and will favor the growth of molds, both of which will generate heat. The purpose of the experiments herein recorded was to determine: (1) the lower moisture limits at which mold growth could be observed to take place; (2) the influence of temperature in connection with moisture upon the degree of damage; (3) the effect of varying the amount of air upon deterioration; (4) the effect of inhibiting mold growth in preventing damage to stored wheat; (5) the influence of time or duration of storage upon the rate of deterioration; and (6) the relative effect of natural or inherent moisture as compared with moisture added artificially in causing damage.

METHODS

In view of the number of comparisons it was desired to make, experiments involving storage in farm bins were impossible. Gallon glass bottles were found to hold an adequate quantity of grain to make possible the desired analyses, including milling and baking determinations, and at the same time permit certain observations, such as mold growth, without distributing the sample; hence, bottles were employed as containers. Two series of experiments were conducted: (1) upon grain recently cut (designated, in these studies, as new wheat), and (2) upon grain five months after harvest which had passed through the post-ripening period (designated as old wheat).

The moisture content of the old wheat was varied by adding to weighed portions of the wheat in the bottles, usually 2200 grams, the calculated quantities of water to give moisture contents of 12%, 14%, 15%, 16%, 18%, and 20%. The mixture of grain and water was agitated several times in order to secure a uniform distribution of moisture. The new wheat was cut at four different stages of maturity and

[1] Contribution No. 45, Department of Milling Industry.

was found to contain 20.4%, 17.4%, 14.1%, and 11.1% of moisture, respectively. This moisture is designated as natural or inherent moisture. Portions of the last cutting were brought up to moisture contents of 20.4%, 17.4%, and 14.1% as was described for old wheat.

Temperature variations in the old wheat studies were obtained by storing the bottles outdoors and in the laboratory during the winter of 1931–32. Bottles of new wheat were stored (1) in the cheese room of the Dairy Department at a temperature of 60° F., (2) in a thermostatically controlled box with a temperature near 95° F. and (3) in the laboratory during the summer of 1932.

Aeration was varied by sealing some bottles, by closing the mouth of other bottles with a wad of cotton, and by drawing air through other bottles by means of air suction. In the latter case the bottle stoppers were provided both with an aspirator tube reaching almost to the bottom of the bottle, and another tube just passing through the stopper. The suction was attached to the short tube so that air withdrawn must pass through the mass of wheat. To prevent loss of moisture, the air entering the bottles was drawn through a wash bottle of water. This also facilitated regulating the rate of flow of air. Aeration was usually continued for one-half hour each day. From the calculated volume of air in the bottle and the rate of flow this was deemed adequate to give a number of complete changes of air each time.

Mold growth was inhibited by the exclusion of air in the sealed bottles and by the use of "Ceresan" (composed of 2% ethyl mercury chloride in 98% finely powdered, dry, inert material). Preliminary trials showed that the use of this material in certain amounts did not injure the viability of the grain, and that one part in 300 of grain would prevent observable mold growth. There seems to be no satisfactory method of measuring the rate or quantity of mold growth and such data as here recorded are based on simple observations with the unaided eye.

The time factor was studied by varying the storage periods from 1 to 16 weeks.

The relative significance of inherent as compared with added moisture was studied by storing the bottles of grain cut at different stages and containing varying percentages of inherent moisture under conditions identical with that of the grain cut at the last stage and wetted to contain corresponding percentages of moisture.

Damage as Measured by Commercial Grading

Studies with Old Wheat

The judging for amount of damage by commercial grading was done on the samples from the old wheat by O. F. Phillips, Chairman, Board

of Review, Federal Grain Supervision, Chicago, Illinois, and on the new wheat by Prof. J. W. Zahnley of the Department of Agronomy. These data are assembled in Tables I and II. The percentage of damage to the old wheat, as indicated in Table I, was surprisingly low. The wheat samples having 12% and 14% moisture had none or only a trace of damaged wheat perceptible. One 15% and one 16% moisture wheat sample had 1% damage, the other samples showed only a trace. The 18% moisture sealed samples showed only a trace of damgae. Tests

TABLE I

DEVELOPMENT OF DAMAGE. (*Old wheat.*)
(Tests conducted in the winter)

Condition or treatment	Time of storage	Percentage of moisture while in storage				
		12	14	16	18	20
	Weeks	*Percentage of damaged kernels*				
Stored in Laboratory						
Limited air	16	Trace	Trace	Trace		Rotten
Sealed	16	"	"	1.0		1.0
Stored outdoors						
Limited air	16	Trace	Trace	Trace	1.5	2.0
Sealed	16	"	"	"	Trace	Trace
		Percentage of moisture while in storage				
		12	15	18		
		Percentage of damaged kernels				
Stored in laboratory						
Sealed	1	—	Trace	Trace		
	2	—	"	"		
	4	Trace	"	"		
	7	"	"	"		
	11	"	1.0	"		
	16	None	Trace	"		
Abundant air	1	Trace	Trace	Trace		
	2	"	"	"		
	4	"	"	"		
	7	"	"	Musty		
	11	"	"	Musty sour		
	16	"	"	" "		
Limited air	1	—	Trace	Trace		
	2	—	"	1.0		
	4	—	"	2.0		
	7	—	"	7.0		
	11	—	"	Rotten		
	16	—		"		

TABLE II

NUMERICAL GRADE AND PERCENTAGE OF DAMAGE. (*New wheat.*)

(Tests conducted in the summer)

Nature of moisture	Treatments	Temperature of storage	Time of storage	Percentage of moisture while stored							
				11.1		14.1		17.4		20.4	
				Numerical grade	Condition of wheat	Numerical grade	Condition of wheat	Numerical grade	Condition of wheat	Numerical grade	Condition of wheat
		F.	*Weeks*								
Natural	Limited air	60	13	2	Sound	2	Sound	1	Sound	2	Sound
	Sealed	60	13	2	Sound	2	Sound	1	Sound	5	Slightly sour
	Ceresan and limited air	60	13	4	Sound	3	Sound	3	Sound	3	Sound
	Ceresan and sealed	60	13	3	Sound	3	Sound	3	Sound	3	Sound
Added	Limited air	60	13			2	Sound	2	Sound	3	Sound
	Sealed	60	13			2	Sound	2	Sound	5	Slightly sour
	Ceresan and limited air	60	13			4	Sound	4	Sound	4	Sound
	Ceresan and sealed	60	13			3	Sound	4	Sound	5	Bad odor
Natural	Limited air	95	13	3	Sound	3	Occasionally a sick kernel	S.G.[1]	Very musty, sick and moldy kernels	S.G.	Sour, moldy
	Sealed	95	13	2	Sound	2	Sound	S.G.	Sick, slightly sour odor	S.G.	Sour, no mold
	Ceresan and limited air	95	13	3	Sound	3	Sound	S.G.	Sour sick kernels	S.G.	Treated, sick, approaching heat damage
	Ceresan and sealed	95	13	3	Sound	3	Sound	S.G.	Sick	S.G.	Heat damaged
Added	Limited air	95	13			3	Sound	S.G.	Very musty, moldy, badly damaged	S.G.	Very sour, moldy, approaching decay
	Sealed	95	13			2	Sound	S.G.	Sick, some kernels approaching heat damage	S.G.	Sour, total damage, sick

[1] Sample grade.

[1] Sample grade.

TABLE II—*Continued*

Nature of moisture	Treatments	Temperature of storage	Time of storage	Percentage of moisture while stored							
				11.1		14.1		17.4		20.4	
				Numerical grade	Condition of wheat	Numerical grade	Condition of wheat	Numerical grade	Condition of wheat	Numerical grade	Condition of wheat
		F.	*Weeks*								
Added	Ceresan and limited air	95	13			S.G.	Few endosperms slightly darkened	S.G.	Approaching heat damage	S.G.	Mold, putrid odor, sour, parched and burned
	Ceresan and sealed	95	13			S.G.	Few endosperms slightly darkened	S.G.	Total damage sick, sour	S.G.	Total damage, sick, sour
Natural	Limited air	Lab.	2			2	Sound	no sample		3	Sound
		Lab.	4			2	Sound	5	Slightly musty	4	Sound
		Lab.	7			S.G.	Sound	S.G.	Damage, musty	S.G.	Very moldy, approaching decay
		Lab.	10			2	Sound	S.G.	Damage, musty	S.G.	Very moldy and decayed
		Lab.	13			2	Sound	S.G.	Damage, very musty	S.G.	Very moldy and decayed
	Sealed	Lab.	2			S.G.	Sound, weevily, and weevil bored kernels	2	Sound, slight weevil odor	2	Sound, weevil odor
		Lab.	4			2	Sound	5	Slightly sour	S.G.	Sick
		Lab.	7			2	Sound	5	Damaged kernels, sick	S.G.	Some heated
		b.	10			2	Sound	S.G.	Damaged kernels, sick	S.G.	Sick, some heated, slightly sour
		Lab.	13			2	Sound	S.G.	Sour, damaged, sick		

TABLE II—*Continued*

Nature of moisture	Treatments	Temperature of storage	Time of storage	Percentage of moisture while stored							
				11.1		14.1		17.4		20.4	
				Numerical grade	Condition wheat	Numerical grade	Condition of wheat	Numerical grade	Condition of wheat	Numerical grade	Condition of wheat
		F.	*Weeks*								
Natural	Abundant air	Lab.	2			2	Sound	5	Slightly musty, some moldy kernels	2	Sound, weevil odor
		Lab.	4			5	Sound	5	Musty, few sick kernels	5	Total damage, sick, weevil bored
		Lab.	7			S.G.	Sound	5	Musty, sick kernels	S.G.	Sick
		Lab.	10			S.G.	Sound	S.G.	Damaged, musty	S.G.	Sick, heat damaged
		Lab.	13			S.G.	Sound	S.G.	Damaged, very musty	S.G.	Moldy kernels
Added	Limited air	Lab.	2			Consumed by weevil		3	Damaged kernels	5	Musty, some sick kernels
		Lab.	4			Consumed by weevil		S.G.	Sick, musty	S.G.	Moldy
		Lab.	7			2	Sound	S.G.	Very moldy	S.G.	Moldy
		Lab.	10			2	Sound	S.G.	Moldy, weevil eaten	S.G.	Moldy
		Lab.	13			2	Sound	S.G.	Moldy	S.G.	Moldy
	Sealed	Lab.	2			2	Sound	2	Sound	3	Sound
		Lab.	4			2	Sound	S.G.	Damaged kernels, sick	S.G.	Sour
		Lab.	7			2	Sound	S.G.	Damaged kernels, sick	S.G.	Damaged kernels, sick
		Lab.	10			2	Sound	S.G.	Damaged kernels, sick	S.G.	Damaged kernels, sour
		Lab.	13			2	Sound	S.G.	Damaged kernels, sick, approaching heat damage	S.G.	Damaged kernels, sour
	Abundant air	Lab.	2			2	Sound	3	Sound	3	Sound
		Lab.	4			2	Sound	S.G.	Sick	5	Damaged kernels, sick
		Lab.	7			2	Sound	S.G.	Sick	S.G.	Damaged kernels, sick
		Lab.	10			2	Sound	S.G.	90% sick kernels, slightly musty	S.G.	Damaged kernels, moldy
		Lab.	13			5	Damaged kernels, sick	S.G.	Approaching heat damage	S.G.	Damaged kernels, very moldy

reported in later paragraphs showed that these had suffered considerable damage, but when air is excluded mold growth does not take place and the amount of damage cannot be accurately appraised by visual observation. When mold growth has taken place it is easier to appraise the damage than when mold is inhibited by excluding the air. The samples treated with Ceresan were ommitted from the judging of old wheat since its presence made it very difficult to appraise the true condition. Certain tests showed that the wheats treated with Ceresan had suffered less damage than those where mold growth was not inhibited; other tests however indicated that Ceresan, although it inhibited mold growth in most cases, did not prevent damage from taking place in high moisture wheat. Two samples stored with 18% and 20% moisture were rotten, one sample had 7% of damaged kernels, but the rest had much less. The wheats which had a limited amount of air suffered more damage than those which had an abundance of air, indicating that a limited amount of air may be more conducive to mold growth than an abundance of air.

Studies with New Wheat

The results from judging the samples of new wheat, given in Table II, show that all the samples having 11.1% moisture were sound whether stored at 60° F. or at 95° F. These may then be regarded as the check samples. The amount of damage was progressively larger with the increase of moisture. Thus there was much more damage at 17.4% than at 14.1%, and more at 20.4% than at 17.4%. All of the samples stored at 60° F. were sound except three of those which had 20.4% moisture. All the samples above 11.1% moisture stored at 95° F. had suffered damage except four of those which had only 14.1% moisture. This shows the importance of low temperature in preventing damage to high moisture wheat.

The amount of damage increased with time. Comparatively little damage was done in the first two weeks. After four weeks the damage was pronounced in the higher moisture samples, growing progressively worse as time increased. Whether the high moisture present is caused by immaturity or from adding water to mature and dry wheat seems to make very little difference. More of the sealed samples graded sound than of those supplied with air. Whether air was supplied in limited amounts or in abundance to the wheats seemed to make very little difference with the new wheats.

Damage as Measured by the Development of Fat Acidity

When certain fats are exposed to conditions which allow autoxidation an acidity develops which will neutralize measurable amounts

of standard alkali. The amount neutralized is an indication of the chemical changes which have taken place. On the basis of these facts, D. A. Coleman [1] has developed a method for determining the amount of damage which takes place in wheat under certain unfavorable storage conditions. The chemical changes which take place in the wheat oil are closely related to those which develop the condition known as rancidity. Hence this term will be used for convenience to designate increases in acidity of fat which take place in wheat when subjected to conditions of high moisture and temperature. The acidity is estimated by first extracting the fat with petroleum ether from the finely ground wheat and then determining the number of cubic centimeters of standard alkali required to neutralize one gram of this fat. In a previous publication (Fenton and Swanson, 1930) it was shown that when wheat had suffered no damage the rancidity figure was about 8. In damaged samples the figure is much higher. What figure indicates that the wheat is unfit for milling and baking has not been determined. It depends largely on whether all or only part of the wheat has been damaged.

The rancidity figures obtained on the old wheat are given in Table III, and those on the new wheat in Table IV. The determination was not made on all the samples from the new wheat since it was known from previous work that the condition of rancidity would not develop in certain samples. Rancidity did not develop in the samples of old wheat stored outdoors, nor in those which were sealed. A temperature of 60° F. was sufficient to inhibit development of rancidity in the new wheat. Inhibiting mold growth by the use of Ceresan retarded but did not prevent the development of rancidity. The presence of Ceresan made it difficult to observe to what extent the mold growth was inhibited. It is probable that on those samples treated with Ceresan which gave a comparatively high rancidity a considerable mold growth had taken place. Since mold growth and high rancidity figures are closely related, it appears that the conditions which favor mold growth also favor the development of rancidity. Whether the air was admitted in limited amounts or was supplied in abundance seemed to make little difference. The length of time for rancidity to develop was related to the amount of moisture in the wheat, the higher the moisture content, the more rapid the development. Whether the moisture was added or inherent seems to have made little difference, in fact the added moisture seems to have produced more rancidity.

Damage as Measured by the Decrease in Viability

The viability of seeds is lowered by the same factors which cause damage to other quality factors in wheat; in fact it may be said that if

[1] Private communication.

TABLE III

RANCIDITY. MILLIGRAMS KOH NEUTRALIZED BY ONE GRAM OF WHEAT FAT. (*Old wheat.*)

Condition or treatment	Time of storage	Percentage of moisture while in storage				
		12	14	16	18	20
	Weeks	*Mgs. KOH per gram of fat*				
Stored in laboratory						
Limited air	16	7.37	7.65	9.35	24.10	29.40
Sealed	16	7.51	8.07	10.20	7.25	7.55
Ceresan and limited air	16	6.43	7.49	8.55	6.29	34.25
Ceresan and sealed	16	7.38	7.80	8.15	6.92	7.12
Stored outdoors						
Limited air	16	6.70	6.63	6.75	6.45	6.75
Sealed	16	6.65	6.33	6.74	6.33	5.80
Ceresan and limited air	16	6.10	6.20	5.93	6.54	5.76
Ceresan and sealed	16	6.27	6.22	6.30	6.07	5.74

		Percentage of moisture while in storage		
		12	15	18
		Mgs. KOH per gram of fat		
Stored in laboratory				
Sealed	1	5.72	5.74	5.60
	2	5.85	6.30	5.66
	4	8.02	7.80	6.85
	7	6.36	6.90	6.21
	11	7.33	7.97	6.42
	16	7.22	9.14	7.43
Aerated daily	1	5.70	6.35	6.95
	2	6.12	6.35	9.22
	4	7.20	7.90	12.45
	7	6.75	7.50	13.95
	11	7.00	8.58	22.65
	16	7.67	11.10	26.70
Ceresan and aerated daily	1	6.11	6.05	5.40
	2	5.86	7.24	6.79
	4	6.28	6.27	5.85
	7	6.26	7.25	6.48
	11	6.75	7.17	6.09
	16	7.57	8.82	11.80
Limited air	1		6.32	5.80
	2		7.22	8.52
	4		6.42	9.72
	7		7.07	11.02
	11		8.27	14.10
	16		7.98	14.45
Ceresan and limited air	1			5.78
	3			5.60
	4			5.90
	7			6.10
	11			6.83
	16			11.00

TABLE IV

RANCIDITY. MILLIGRAMS KOH NEUTRALIZED BY ONE GRAM OF WHEAT FAT. (*New wheat.*)

Nature of moisture	Treatments	Temperature of storage	Time of storage	Percentage of moisture while in storage [1]		
				14.1	17.4	20.4
		° *F.*	*Weeks*	*Mgs. KOH per gram of fat*		
Natural	Limited air	60	13	5.15	5.60	5.60
Added	" "	60	13	5.60	6.05	8.55
Natural	" "	95	13	9.70		
Added	" "	95	13	8.30		
Natural	Limited air	Lab.	2	8.35		15.0
	" "	Lab.	4	7.50	17.4	19.65
	" "	Lab.	7	11.55	17.55	24.40
	" "	Lab.	10	8.15	18.00	
	" "	Lab.	13	8.45	24.05	
	Abundant air	Lab.	2	9.65	11.15	9.60
	" "	Lab.	4	7.05	16.80	9.80
	" "	Lab.	7	6.75	22.00	15.70
	" "	Lab.	10	8.10		
	" "	Lab.	13	10.35		
Added	Limited air	Lab.	2	18.50	16.70	21.85
	" "	Lab.	4	14.70	28.30	21.00
	" "	Lab.	7	10.30	36.60	26.60
	" "	Lab.	10	9.50	40.25	
	" "	Lab.	13	11.75		
	Abundant air	Lab.	2	8.90	16.55	10.20
	" "	Lab.	4	10.40	24.25	14.15
	" "	Lab.	7	11.20	35.40	26.60
	" "	Lab.	10	11.65		25.70
	" "	Lab.	13	15.65		

[1] The check sample, 11.1% moisture, had a fat of 8.00.

the viability has not been affected, no damage has taken place. However, the power to germinate is the first factor to be destroyed and this may happen before very much damage has been done to the milling and baking qualities. If the seed is all dead then it is very probable that the quality has been seriously affected. If only a small percentage of the seed of the season's crop is dead then the wheat may still be suitable for making into flour (Swanson and Fenton, 1932). The time which has elapsed since viability was destroyed seems to make a large difference as was shown by the very poor milling and baking qualities of a very old wheat which was all dead (Swanson, 1926).

The viability was determined by the seed laboratory under the direction of Prof. Zahnley at the end of the storage period, and after the

samples had been thoroughly air dried. The figures obtained on the old wheat are given in Table V, and those on the new wheat in Table VI. The viability of samples in which no injury had taken place was around 95. The samples from the old wheat stored outdoors had only a very slight decrease in viability even at 18% and 20% moisture. The samples from the new wheat stored at 60° F. had a slight decrease at 20.4% moisture. All the samples of the old wheat stored at 20% moisture in the laboratory were dead, and of the new wheat even those stored with 17.4% at 95° F. were dead. The lesser injury to the old wheat at 18% was due to the lower temperature of the laboratory, which during the winter probably averaged about 70° F.

TABLE V

PERCENTAGE OF VIABILITY. (*Old wheat.*)

Condition or treatment	Time of storage	Percentage of moisture while in storage				
		12	14	16	18	20
	Weeks	*Percentage of viability*				
Stored in laboratory						
Limited air	16	95	93	65	22	0
Sealed	16	93	83	25	1	0
Ceresan and limited air	16	86	78	75	54	
Ceresan and sealed	16	85	83	34	17	0
Stored outdoors						
Limited air	16	96	96	96	81	93
Sealed	16	93	94	95	95	94
Ceresan and limited air	16	96	96	93	89	93
Ceresan and sealed	16	95	94	96	93	92
		Percentage of moisture while in storage				
		12	15	18		
		Percentage of viability				
Stored in laboratory	1	95	94	95		
Sealed	2	95	97	94		
	4	95	95	96		
	7	93	92	94		
	11	92	91	85		
	16	96	82	7		
Aerated daily	1	93	95	92		
	2	95	94	67		
	4	93	91	41		
	7	89	95	33		
	11	94	77	22		
	16	89	42	22		

TABLE V—*Continued*

Condition or treatment	Time of storage	Percentage of moisture while in storage		
		12	15	18
	Weeks	*Percentage of viability*		
Stored in laboratory				
Ceresan and aerated daily	1	89	89	95
	2	93	92	89
	4	93	88	89
	7	88	91	79
	11	79	88	58
	16	79	69	20
Limited air	1		87	95
	2		91	75
	4		92	63
	7		94	43
	11			32
	16		97	26
Ceresan and limited air	1			91
	2			87
	4			94
	7			85
	11			70
	16			38

Low temperature seems to be the important factor in preventing injury to viability. Excluding air by sealing had a small detrimental effect even when the samples were stored at low temperatures, and the Ceresan also appears to have had some injurious effect on viability. Whether air was supplied in abundance or in limited amounts seemed to make but little difference. The added moisturue seems to have been more injurious than the natural moisture. The duration of the storage conditions was also important. Very little injury took place in one or two weeks even at the higher moisture contents, but after that the injury became progressively greater as time went on, and the higher the moisture, the greater the injury.

Damage as Measured by Effect on Test Weight

The data on test weight on the old wheat are given in Table VII, and on the new wheat in Table VIII. The highest test weight was obtained on the wheat cut at 17.1% moisture and stored at 60° F. where no injury had taken place. The test weight was progressively less in sound wheat cut at 14.1% and 11% moisture. The wheat cut at 20.4% moisture was apparently well filled but evidently not as well as that cut at 17.1%. Why there should be a decrease when the wheat was cut at 14.1% and 11% moisture is not apparent.

The test weight is influenced not only by the plumpness or volume weight of the wheat, but also by the following factors: the present moisture content, the previous moisture condition, and material on the bran coat which influences the packing effect in the kettle. Test weight may also be influenced by shape of kernels, but this factor did not enter into these determinations.

The presence of Ceresan decreased the test weight approximately 3 points in the samples in which no damage had occurred, such as those stored outdoors in the winter and in the box at 60° F. This is accounted for by the fact that the light powdery material on the bran sur-

TABLE VI

PERCENTAGE OF VIABILITY. (*New wheat.*)

Nature of moisture	Treatments	Temperature of storage	Time of storage	Percentage of moisture while in storage			
				11	14.1	17.4	20.4
		° F.	*Weeks*	*Percentage of viability*			
Natural	Limited air	60	13	95	93	96	78
	Sealed	60	13	91	96	91	89
	Ceresan and limited air	60	13	94	97	93	87
	Ceresan and sealed	60	13	97	98	94	92
Added	Limited air	60	13		98	95	91
	Sealed	60	13		97	98	93
	Ceresan and limited air	60	13		96	96	90
	Ceresan and sealed	60	13		96	90	94
Natural	Limited air	95	13	96	93	0	0
	Sealed	95	13	98	87	0	0
	Ceresan and limited air	95	13	91	90	0	0
	Ceresan and sealed	95	13	86	81	0	0
Added	Limited air	95	13		97	0	0
	Sealed	95	13		6	0	0
	Ceresan and limited air	95	13		34	0	0
	Ceresan and sealed	95	13		0	0	0
Natural	Limited air	Lab.	2		95	91	79
		Lab.	4		98	70	57
		Lab.	7		94	56	11
		Lab.	10		96	14	0
		Lab.	13		92	9	0
Natural	Sealed	Lab.	2		93	97	84
		Lab.	4		92	88	0
		Lab.	7		96	15	0
		Lab.	10		94	0	0
		Lab.	13		92	0	0

TABLE VI—*Continued*

Nature of moisture	Treatments	Temperature of storage	Time of storage	Percentage of moisture while in storage			
				11	14.1	17.4	20.4
		° *F.*	*Weeks*	*Percentage of viability*			
Natural	Abundant air	Lab.	2		88	90	86
		Lab.	4		95	59	20
		Lab.	7		97	49	0
		Lab.	10		95	7	0
		Lab.	13		91	0	1
Added	Limited air	Lab.	2		85[1]	69	51
		Lab.	4		97	29	22
		Lab.	7		98	12	0
		Lab.	10		93	0	0
		Lab.	13		58	0	0
Added	Sealed	Lab.	2		98	99	58
		Lab.	4		96	0	0
		Lab.	7		98	0	0
		Lab.	10		97	0	0
		Lab.	13		95	0	0
Added	Abundant air	Lab.	2		98	79	79
		Lab.	4		98	45	25
		Lab.	7		95	0	4
		Lab.	10		90	0	0
		Lab.	13		40	0	0

[1] Weevil eaten.

face kept the kernels further apart. That moisture content by itself influences the test weight has been shown by Swanson and Pence (1932), who found that increasing the moisture of the wheat decreased the test weight approximately one point for each percent of added moisture. The test weight on all these samples was taken after they were thoroughly air dry and of uniform moisture content, and hence the lower test weight of the wheat which had the high moisture content when stored outdoors in the winter and at 60° F. was not therefore either due to damage or high moisture content at the time of making the test weight but to the swelling effect of the water added when preparing these wheats for storage. It seems that when water is added to wheat which has once been dry there is a swelling effect which partially remains after the wheat is again dried.

Where excessive mold growth had taken place there was a large decrease in test weight due to the destruction of material. When air was supplied in limited amounts there was a greater decrease in test weight

than when air was supplied in abundance. The sealed samples suffered the least effect on test weight, but from tests reported in a subsequent paragraph it will be shown that some of these had suffered serious damage in their baking qualities. The duration of the unfavorable conditions progressively decreased the test weight. Thus there was very little decrease for the high moisture wheats in the first few weeks, but after 13 or 16 weeks the decrease was considerable.

Influence of Added Water on Sugar Content and on Diastatic Activity

Will the addition of water to mature dry wheat and then storing for some time increase the sugar content or the diastatic activity? Analyzing the flour from the samples of old wheat stored with various amounts of moisture for the amount of sugar present, and also that produced

TABLE VII

Test Weight as Affected by Storage Conditions. (*Old wheat.*)

Condition or treatment	Time of storage	Percentage of moisture while in storage				
		12	14	16	18	20
	Weeks	*Test weight per bushel, Lbs.*				
Stored in laboratory						
Limited air	16	60.3	59.1	57.1	53.7	43.6
Sealed	16	60.0	59.1	57.9	57.5	56.4
Ceresan and limited air	16	57.4	56.1	55.4	55.0	52.5
Ceresan and sealed	16	57.5	56.0	55.1	55.0	54.2
Stored outdoors						
Limited air	16	60.4	59.1	58.4	58.1	56.3
Sealed	16	60.4	58.7	58.3	58.1	57.9
Ceresan and limited air	16	57.1	55.8	55.2	55.0	54.7
Ceresan and sealed	16	57.5	55.7	55.1	56.0	55.6
		Percentage of moisture while in storage				
		12	15	18		
		Test weight per bushel, Lbs.				
Stored in laboratory						
Sealed	1	60.7	58.7	58.2		
	2	59.4	58.6	58.2		
	4	59.7	58.3			
	7	59.5	58.3	57.7		
	11	59.4	58.0	57.3		
	16	59.3	58.7	56.7		

TABLE VII—*Continued*

Condition or treatment	Time of storage	Percentage of moisture while in storage		
		12	15	18
	Weeks	*Test weight per bushel, Lbs.*		
Stored in laboratory				
Aerated daily	1	59.8	58.4	58.0
	2	59.6	58.3	56.0
	4	59.6	58.2	55.5
	7		58.3	55.4
	11	59.1	57.3	54.7
	16	59.3	55.9	54.8
Ceresan and aerated daily	1	57.3	55.7	55.2
	2	56.5	55.9	55.2
	4	56.7	55.9	55.1
	7	56.3	55.5	54.6
	11	56.6	55.7	54.6
	16	56.4	55.5	53.6
Limited air	1		58.6	58.0
	2		58.5	56.7
	4		58.5	56.4
	7		58.6	56.1
	11		58.6	56.5
	16			
Ceresan and limited air	1			55.5
	2			55.2
	4			55.4
	7			55.2
	11			55.1

after one hour's digestion in water, would furnish an answer to this question. The method used was essentially that of Blish and Sandstedt (1933) who had kindly furnished prepublication directions. The amounts of sugar present before digestion are given in Table IX, and the additional amounts produced during one hour's digestion are given in Table X. The former indicates whether any sugar was produced during the storage period, and the latter the influence of the conditions of storage on diastatic activity.

Only the samples which had 20% moisture and were stored in the laboratory showed any increase in the amount of sugar. These samples had all suffered serious damage as shown by zero viability, and high fat acidity in samples to which the air had access. None of the samples at 18% or less moisture showed any increase in sugar over those which had 12%, or where none would be expected.

The diastatic activity as measured by the amounts of sugar pro-

duced by digesting in water for one hour was greatest in those samples which were stored under conditions in which no damage would take place, that is, low temperature and low moisture.

In the sealed samples there was a higher diastatic activity when the moisture content was 18% than when it was 15% with the exception of the one wheat stored 16 weeks. In the others, with only one minor exception, there was a greater diastatic activity when the moisture during storage was 15% than at the larger percentages. Thus it seems that the high moistures which are most likely to cause damage also decrease the diastatic activity. Why the exclusion of air should allow an opposite

TABLE VIII

TEST WEIGHT AS AFFECTED BY STORAGE CONDITIONS. (*New wheat.*)

Nature of moisture	Treatments	Temperature of storage	Time of storage	Percentage of moisture while in storage			
				11.0	14.1	17.4	20.4
		° *F.*	*Weeks*	*Test weight per bushel, Lbs.*			
Natural	Limited air	60	13	58.7	59.3	60.1	59.0
	Sealed	60	13	58.5	59.5	60.1	59.9
	Ceresan and limited air	60	13	55.7	57.0	57.4	57.1
	Ceresan and sealed	60	13	56.1	56.9	57.3	56.9
Added	Limited air	60	13		58.6	58.5	56.6
	Sealed	60	13		59.2	58.0	57.9
	Ceresan and limited air	60	13		55.8	55.7	55.7
	Ceresan and sealed	60	13		56.0	55.8	55.5
Natural	Limited air	95	13	57.9	58.8	56.0	47.1
	Sealed	95	13	58.5	59.3	59.0	57.7
	Ceresan and limited air	95	13	56.1	56.8	56.9	55.8
	Ceresan and sealed	95	13	56.2	56.9	56.7	55.5
Added	Limited air	95	13		58.7	50.6	46.7
	Sealed	95	13		58.4	57.7	57.2
	Ceresan and limited air	95	13		55.9	55.0	48.0
	Ceresan and sealed	95	13		56.0	55.0	54.9
Natural	Limited air	Lab.	2		59.5	59.5	57.9
		Lab.	4		59.7	57.9	54.9
		Lab.	7		58.0	57.8	50.9
		Lab.	10		59.7	57.8	48.8
		Lab.	13		59.4	57.2	47.2
	Sealed	Lab.	2		57.6	59.8	58.7
		Lab.	4		59.5	59.7	58.2
		Lab.	7		59.6	60.4	58.2
		Lab.	10		59.3	59.9	58.0
		Lab.	13		59.6	59.5	57.7

TABLE VIII—*Continued*

Nature of moisture	Treatments	Temperature of storage	Time of storage	Percentage of moisture while in storage			
				11.0	14.1	17.4	20.4
		° *F.*	*Weeks*	*Test weight per bushel, Lbs.*			
	Abundant air	Lab.	2		57.6	59.7	58.8
		Lab.	4		59.7	58.3	58.0
		Lab.	7		59.8	57.9	57.8
		Lab.	10		59.1	57.3	57.5
		Lab.	13		57.6	57.0	56.7
Added	Limited air	Lab.	2		55.5	57.7	54.8
		Lab.	4		57.5	55.1	51.9
		Lab.	7		58.1	53.3	49.8
		Lab.	10		58.4	52.2	48.3
		Lab.	13		58.3	52.4	46.6
	Sealed	Lab.	2		59.1	58.5	57.4
		Lab.	4		59.8	58.6	57.5
		Lab.	7		58.7	57.4	57.4
		Lab.	10		58.6	57.6	56.9
		Lab.	13		58.2	57.0	57.9
Added	Abundant air	Lab.	2		58.8	56.7	57.8
		Lab.	4		58.4	56.4	57.0
		Lab.	7		58.0	55.9	55.0
		Lab.	10		58.2	55.1	54.8
		Lab.	13		56.9	55.2	55.2

tendency is not apparent. The important fact observed is that neither the total sugar present nor the diastatic activity may be increased by adding water to wheat in such amounts as would be used in tempering or even in such amounts as to cause some damage.

Damage as Measured by Baking Tests [2]

The most significant figures obtained in the baking tests were loaf volumes and texture grades. The former is an accurate measure in cubic centimeters, but the latter is one of judgment expressed on the basis of 100 being perfect, and 80, very poor. Experience has shown that differences in loaf volumes must be fairly large in order to be really significant in baking tests such as these. The figures for texture express gluten quality as far as that is revealed in the bread crumb. Injury to gluten quality is shown in the lack of that fine silky texture such as is obtained in the crumb from a good bread flour.

[2] Acknowledgment and expression of appreciation are given to Earl B. Working who performed the baking tests.

The baking method was chosen with reference to the purposes in view. In these tests the formula and the method were adapted to reveal weaknesses in the flour. The formula was as follows:

Flour	250	gms.
Sugar	15	"
Salt	4.5	"
Lard	2.5	"
Yeast	4.4	"
NH_4Cl	0.125	gm.

Water according to absorption

The mixing time was just sufficient to develop the dough which was fermented for 2 hours and 40 minutes when it was given the first punch. Then it was given another fermentation of 20 minutes after which it was panned. The proofing was done in the cylindrical baking pans

TABLE IX

DEVELOPMENT OF TOTAL SUGARS

Condition or treatment	Time of storage	Percentage of moisture while in storage				
		12	14	16	18	20
	Weeks	*Percentage of total sugars*				
Stored in laboratory						
Limited air	16	0.356	0.277	0.36	0.315	0.605
Sealed	16	.408	.338	.338	.449	.694
Ceresan and limited air	16	.326	.290	.328	.375	.570
Ceresan and sealed	16	.366	.362	.380	.380	.731
Stored outdoors						
Limited air	16	.366				
Sealed	16	.338				
Ceresan and limited air	16	.300				
Ceresan and sealed	16	.286				

		Percentage of moisture while in storage		
		12	15	18
		Percentage of total sugars		
Stored in laboratory				
Sealed	1		0.333	0.344
	2		.324	.338
	4		.316	.288
	7		.494	.350
	11		.290	.382
	16		.315	.432

TABLE IX—*Continued*

Condition or treatment	Time of storage	Percentage of moisture while in storage		
		12	15	18
	Weeks	*Percentage of total sugars*		
Stored in laboratory				
Aerated daily	1		.285	.290
	2		.315	.350
	4		.297	.310
	7		.305	.362
	11		.312	.366
	16		.333	.390
Ceresan and aerated daily	1		.323	.314
	2		.268	.300
	4		.314	.313
	7		.319	.362
	11		.314	.417
	16		.319	.432
Limited air	1		.288	.293
	2		.282	.323
	4		.313	.300
	7		.304	.296
	11		.285	.296
	16		.293	.318
Ceresan and limited air	1			.285
	2			.282
	4			.363
	7			.340
	11			.397

(Swanson *et al.*, 1915) and was continued until the dough had reached a uniform height as measured by the plunger supported by the disc resting on the dough. Since chemical tests had already been made for diastatic activity, an excess sugar was used so that gas development would not be a limiting factor. The data on loaf volumes for the old wheat are found in Table XI and for the new wheat in Table XII. The data on texture of the old wheat are found in Table XIII and for new wheat in Table XIV.

That excess moisture when the temperatures were low was not detrimental to loaf volume is shown by the results on the samples stored outdoors. At the temperature of the laboratory an injury was effected in the samples having 16% or more moisture. That the trace of Ceresan which could not be removed by scouring was harmful is shown by the results from the wheat which had only 12% moisture, and hence had suffered no damage. Therefore, it is difficult to know how much value

TABLE X

PERCENTAGE OF SUGAR PRODUCED BY DIGESTING FOR 1 HOUR

Condition or treatment	Time of storage	Percentage of moisture while in storage				
		12	14	16	18	20
	Weeks	*Percentage of sugars due to diastasis*				
Stored in laboratory						
Limited air	16	0.794	0.733	0.710	0.835	0.645
Sealed	16	.787	.842	.624	.491	.466
Ceresan and limited air	16	.684	.760	.624	.581	.767
Ceresan and sealed	16	.763	.848	.584	.534	.344
Stored outdoors						
Limited air	16	.764				
Sealed	16	.842				
Ceresan and limited air	16	.890				
Ceresan and sealed	16	.854				

		Percentage of moisture while in storage		
		12	15	18
		Percentage of sugars due to diastasis		
Stored in laboratory				
Sealed	1		0.577	0.701
	2		.726	.727
	4		.688	.807
	7		.576	.590
	11		.600	.603
	16		.625	.443
Stored in laboratory				
Aerated daily	1		.681	.665
	2		.660	.585
	4		.803	.514
	7		.682	.488
	11		.613	.361
	16		.583	.404
Ceresan and aerated daily	1		.907	.743
	2		.662	.691
	4		.616	.587
	7		.656	.598
	11		.816	.711
	16		.601	.578
Limited air	1		.832	.743
	2		.798	.644
	4		.842	.603
	7		.581	.559
	11		.800	.417
	16		.601	.377
Ceresan and limited air	1			.630
	2			.728
	4			.595
	7			.510
	11			.508
	16			

TABLE XI

LOAF VOLUMES. (*Old wheat.*)

Condition or treatment	Time of storage	Percentage of moisture while in storage				
		12	14	16	18	20
	Weeks	*Loaf volumes in Cc.*				
Stored in laboratory						
Limited air	16	1470	1545	1495	1410	1265
Sealed	16	1560	1500	1430	1305	1410
Ceresan and limited air	16	1430	1370	1360	1240	1085
Ceresan and sealed	16	1530	1440	1240	1140	1170
Stored outdoors						
Limited air	16	1545	1530	1530	1510	1510
Sealed	16	1570	1515	1560	1515	1470
Ceresan and limited air	16	1485	1510	1480	1480	1440
Ceresan and sealed	16	1470	1500	1410	1440	1360

		Percentage of moisture while in storage		
		12	15	18
		Loaf volumes in Cc.		
Stored in laboratory				
Sealed	1	1490	1560	1470
	2	1445	1570	1480
	4	1495	1510	1355
	7	1525	1485	1440
	11	1510	1470	1340
	16	1550	1470	1370
Stored in laboratory				
Aerated daily	1	1545	1505	1590
	2	1575	1545	1480
	4	1485	1490	1470
	7	1500	1545	1390
	11	1490	1480	1350
	16	1490	1360	1330
Ceresan and aerated daily	1	1510	1400	1490
	2	1525	1440	1420
	4	1495	1450	1405
	7	1495	1440	1335
	11	1530	1445	1230
	16	1550	1430	1260
Limited air	1		1510	1510
	2		1480	1470
	4		1520	1450
	7		1490	1380
	11		1490	1380
	16		1490	1340
Ceresan and limited air	1			1560
	2			1465
	4			1400
	7			1330
	11			1280
	16			1315

TABLE XII

LOAF VOLUMES. (*New wheat.*)

Nature of moisture	Treatments	Temperature of storage	Time of storage	Percentage of moisture while in storage			
				11.1	14.1	17.4	20.4
		° *F.*	*Weeks*	*Loaf volumes in Cc.*			
Natural	Limited air	60	13	1770	1775	1525	1610
	Sealed	60	13	1695	1660	1690	1545
Added	Limited air	60	13		1790	1780	1690
	Sealed	60	13		1800	1760	1670
Natural	Limited air	95	13	1720	1555		
	Sealed	95	13	1745	1620		
Added	Limited air	95	13		1750		
	Sealed	95	13		1700		
Natural	Limited air	Lab.	2			1640	1570
		Lab.	4			1540	1510
		Lab.	7			1510	1530
		Lab.	10			1510	
		Lab.	13			1460	
	Sealed	Lab.	2			1550	1490
		Lab.	4			1490	1480
		Lab.	7			1490	
		Lab.	10			1440	
	Abundant air	Lab.	2			1540	1570
		Lab.	4			1490	1530
		Lab.	7			1470	1530
		Lab.	10			1420	
Added	Limited air	Lab.	2			1670	1760
		Lab.	4			1605	1610
		Lab.	7			1605	
		Lab.	10			1580	
	Sealed	Lab.	2			1680	1610
		Lab.	4			1570	1575
	Abundant air	Lab.	2			1715	1635
		Lab.	4			1615	1605
		Lab.	7			1470	1560

TABLE XIII

CRUMB TEXTURE. (*Old wheat.*)

(100 = perfect, 80 = very poor.)

Condition or treatment	Time of storage	Percentage of moisture while in storage				
		12	14	16	18	20
	Weeks	*Relative values*				
Stored in laboratory						
Limited air	16	98	99	96	92	92
Sealed	16	99	98	92	90	92
Ceresan and limited air	16	96	92	92	88	80
Ceresan and sealed	16	94	94	90	88	88
Stored outdoors						
Limited air	16	94	99	98	98	92
Sealed	16	97	92	97	94	91
Ceresan and limited air	16	94	94	90	92	88
Ceresan and sealed	16	92	97	88	92	85

		Percentage of moisture while in storage		
		12	15	18
		Relative values		
Stored in laboratory				
Sealed	1	97	97	96
	2	95	98	94
	4	95	98	90
	7	97	97	90
	11	96	95	88
	16	97	98	88
Stored in laboratory				
Aerated daily	1	97	98	96
	2	96	98	96
	4	97	97	94
	7	95	98	92
	11	97	95	88
	16	95	88	85
Ceresan and aerated daily	1	96	93	94
	2	96	95	94
	4	97	93	90
	7	95	93	88
	11	96	93	85
	16	96	93	85
Limited air	1		98	97
	2		98	97
	4		98	92
	7		98	92
	11		98	87
	16		97	87
Ceresan and limited air	1			94
	2			94
	4			92
	7			89
	11			87
	16			87

TABLE XIV

CRUMB TEXTURES. (*New wheat.*)
(100 = perfect, 80 = very poor)

Nature of moisture	Treatments	Temperature of storage	Time of storage	Percentage of moisture while in storage			
				11.1	14.1	17.4	20.4
		° *F.*	*Weeks*	*Relative values*			
Natural	Limited air	60	13	98	99	96	96
	Sealed	60	13	98	97	97	96
Added	Limited air	60	13		97	97	97
	Sealed	60	13		98	98	97
Natural	Limited air	95	13	98	96		
	Sealed	95	13	98	98		
Added	Limited air	95	13		97		
	Sealed	95	13		97		
Natural	Limited air	Lab.	2			93	94
		Lab.	4			91	98
		Lab.	7			89	80
		Lab.	10			85	
		Lab.	13			85	
	Sealed	Lab.	2			95	91
		Lab.	4			91	88
		Lab.	7			85	
		Lab.	10			85	
	Abundant air	Lab.	2			91	94
		Lab.	4			89	94
		Lab.	7			89	85
		Lab.	10			85	
Added	Limited air	Lab.	4			96	96
		Lab.	4			92	86
		Lab.	7			80	
		Lab.	10			80	
	Sealed	Lab.	2			98	93
		Lab.	4			92	91
	Abundant air	Lab.	2			96	95
		Lab.	4			94	95
		Lab.	7			88	88

this substance had in preventing damage by inhibiting mold growth. The duration of the unfavorable conditions was also important. Not much damage took place in the high moisture wheats during the first few weeks, but in 7 to 16 weeks the damage was serious. The samples from which air was excluded entirely by sealing the bottles suffered more damage than those which had access to air, particularly those which were stored warm. Thus while excluding the air inhibited mold growth, it did not prevent deterioration in baking value. The sealed samples showed that there was no notable increase in acidity. Whether air was supplied abundantly or in limited amounts seemed to make very little difference.

SUMMARY

Mold growth is an indication of damage in stored wheat. The percent of moisture at which molds develop is closely related to the temperature. When wheat was stored in a room held at 60° F., or when placed outdoors during the winter, very little mold growth was observed when the moisture was 20%, and none when it was 18% or lower. When the wheat was stored in a box held at 95° F., or when placed in the laboratory during the winter, some mold growth was observed when the moisture content was 14%, and the extent of growth was greater with larger amounts of moisture.

Whether wheat is high in moisture because of incomplete desiccation during maturing, or because of water added to wheat once dry, seems to make little difference. It is the amount of moisture in connection with the temperature which determines the extent of damage which will take place.

Mold growth may be inhibited by entire exclusion of air. Wheat stored in sealed bottles appeared sound after drying even though the moisture content was high during storage. Inhibition of mold growth by air exclusion does not prevent injury to quality. Whether air is supplied in abundance or in limited amounts seems to make little difference.

Mold growth may also be inhibited by the presence of poisons. This does not prevent injury to quality if the temperature and the moisture are high.

The length of time during which the factors of high moisture and temperatures operate are important. Very little damage took place in a few weeks, but in 13 to 16 weeks the damage in many cases was very severe.

One of the best measures for the extent of damage which has taken place in wheat is the determination of the amount of acidity which has developed in the wheat fat. This is designated as rancidity. The de-

velopment of this condition is, however, related to the air supply. In the entire exclusion of air this will not develop. Hence the conditions which favor the development of mold and rancidity are closely related. However, since damage to quality also took place in the sealed bottles, absence of high rancidity is not proof of lack of damage.

Sugar was not increased until the moisture was above 18%. The diastatic activity was not increased by high moisture; on the contrary the diastatic activity was greatest in the samples stored with low moisture. Thus it is not possible to increase either the sugar content or the diastatic activity by adding water to wheat in amounts which are safe for storage or in amounts used in tempering wheat.

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METHOD OF PRESERVING BREAD FOR PERMANENT GRAIN JUDGING STANDARDS [1]

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A method of scoring the grain of the cut slice of bread was recently reported by Bailey and Markley.[2] The standards used in this method of scoring were made by preserving bread.

The method used to preserve bread has been to dip slices, or half of the 100 gram loaves in a solution composed of one part glycerine, two parts 40% formaldehyde, and one part water by volume. The slices are allowed to soak up this solution to saturation, usually reached within one minute for slices, and two minutes for halves of the small loaves. The slices are then laid face side down on clean boards in a closed space or cabinet and allowed to dry slowly for about one month, after which time they will be ready for mounting. Too rapid drying must be avoided as it will cause the slices to check or crack. When properly prepared the slices are soft and will remain in that state indefinitely.

The slices may be mounted behind glass in a picture frame and used in this manner as standards. Excellent exhibits can be prepared by mounting preserved halves of the small loaves on panels with appropriate legends.

[1] Paper No. 1232 Journal Series, Minnesota Agricultural Experiment Station.
[2] Bailey, C. H., and Markley, M. C. 1933. Scoring crumb grain. Cereal Chem. 10: 545–547.

THE CHEMICAL AND PHYSICO-CHEMICAL CHANGES INDUCED IN WHEAT FLOUR BY ARTIFICIAL MATURING AGENTS

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Introduction

It has long been known that when freshly milled and untreated flour is stored for some time, two changes take place—it gradually loses its yellowish color and at the same time undergoes a change commonly known as maturing or aging, whereby its baking and general handling qualities are improved. In recent years it has been found that these two processes may be hastened by means of various reagents, and their use has become so general that artificial bleaching and maturing is now considered almost an integral part of the milling process.

The two effects, bleaching and maturing, are apparently distinct. Ferrari and Bailey (1929) have summarized the facts regarding the bleaching effect. The exact nature of the chemical and physical changes which take place when flour is naturally or artificially bleached is yet far from being fully determined.

The present paper will discuss the maturing effect or improvement in baking quality. The reagents used were nitrogen trichloride (Agene) and Beta Chlora (which is a mixture of 99.5% chlorine and 0.5% nitrosyl chloride).

Baker (1922), Lawellin (1924), Kent-Jones (1924), Parker (1929), Hanson (1932) and others state that nitrogen trichloride does not appreciably alter the commonly determined characteristics of flour, with the exception of a slight increase in the hydration capacity of the proteins. Published data of the effects of Beta Chlora are meagre, but one of the effects of this reagent is to increase the hydrogen-ion concentration of the flour.

Although it has not been definitely determined how either of these maturing agents bring about improvement, it is easily demonstrated that there is an immediate change in the quality of the gluten, the handling qualities of the dough, and in the characteristics of the baked loaf.

Larmour and Machon (1931) found that the maturing effect of Beta Chlora seemed to be dependent to some extent on the protein con-

tent of straight grade flours milled on the experimental mill. The higher the protein content of the flours the more reagent was required for complete maturation, and the highest protein flours gave the greatest response to treatment.

Working (1928), Geddes (1930), Larmour and Machon (1931), and Geddes and Larmour (1933) believed that the artificial maturation of flour has the same or a similar effect in developing the dough made from that flour as the addition of oxidizing agents to the dough.

Studies Relative to the Effects of Flour Oxidizing Agents on Bread and Dough Qualities

Experimental

In an attempt to determine the reason for the marked improvement in the baking qualities of wheat flour, brought about by the action of artificial maturing agents, a series of sound wheats of the 1932 Western Canadian crop was milled on a laboratory mill. The resultant flours were subjected to analytical and baking tests. Analysis of the samples is given in Table I.

TABLE I

CHEMICAL ANALYSIS OF WHEATS AND FLOURS STUDIED

Protein content		Ash content of flour
Wheat	Flour	
P.ct.	*P.ct.*	*P.ct.*
11.50	10.70	0.48
12.80	11.90	.48
13.20	12.40	.47
14.40	13.50	.47
15.30	14.20	.46
16.50	15.30	.47

Four millings were made of each sample. The flour from each series was thoroughly mixed and bleached with Agene and Beta Chlora at the rates indicated in Tables II and III. The samples were baked on the following day and again after one month's storage. On account of the conclusions reached by the investigators cited above the unbleached flours were also baked with the addition of potassium bromate to the formula. The rates used are indicated in Table IV.

The baking method was that recommended by the Baking Committee of the A. A. C. C., with the following exceptions—variable absorption to suit the flour, and low sided pans.

After baking, the loaves were measured for volume in an apparatus similar to that described by Malloch and Cook (1930). The loaves were

TABLE II

AGENE SERIES

Protein content of flour	Treatment	Loaf volume	Grain and texture	Crust color	General appearance	Computed baking score	Response to treatment: Loaf volume	Response to treatment: Baking score
P.ct.		*Cc.*	*Score*	*Score*	*Score*		*Cc.*	
	Unbleached	550	5 C	4	3 g	77		
	2 gm. Agene	530	6 C	4	5	80	−20	+ 3
10.70	4 gm. Agene	520	6 C	3.5	4.5	79	−30	+ 2
	6 gm. Agene	520	5 c	2 p	3 o	72	−30	− 5
	8 gm. Agene	500	5 c, o	1 v.p	2 v.o	69	−50	− 8
	Unbleached	550	8	4	3 g	86		
	2 gm. Agene	570	8	4	4 g	89	+20	+ 3
11.90	4 gm. Agene	560	10	5	5	95	+10	+ 9
	6 gm. Agene	530	9	3.5 p	4 o	88	−20	+ 2
	8 gm. Agene	520	8	3 p	3 o	82	−30	− 4
	Unbleached	520	8 C	4	3 g	83		
	2 gm. Agene	530	6 C	4	4	79	+10	− 4
12.40	4 gm. Agene	500	9	4	5	86	−20	+ 3
	6 gm. Agene	520	9	5	4	89	+ 0	+ 6
	8 gm. Agene	530	9	4	3 o	87	+10	+ 4
	Unbleached	570	7 C	5	4 g	87		
	4 gm. Agene	610	8	4	3 g	92	+40	+ 5
13.50	6 gm. Agene	600	9	5	5	97	+30	+10
	8 gm. Agene	600	9	5	4.5 o	97	+30	+10
	10 gm. Agene	570	8	5	4 o	90	+ 0	+ 3
	Unbleached	590	7 C	4	3 g	87		
	4 gm. Agene	610	8	5	4	94	+20	+ 7
14.20	6 gm. Agene	630	9	5	5	100	+40	+13
	8 gm. Agene	670	9	5	5	104	−80	+17
	10 gm. Agene	650	8.5	5	5	101	+60	+14
	Unbleached	640	6 C	3 p	3 g	88		
	4 gm. Agene	670	8	4	4 g	99	+30	+11
15.30	6 gm. Agene	670	8	5	4.5	101	+30	+13
	8 gm. Agene	670	9	5	5	104	+30	+16
	10 gm. Agene	690	9	5	5	106	+50	+18

TABLE III

BETA CHLORA SERIES

Protein content of flour	Treatment	Loaf volume	Grain and texture	Crust color	General appearance	Computed baking score	Response to treatment: Loaf volume	Response to treatment: Baking score
P.ct.		*Cc.*	*Score*	*Score*	*Score*		*Cc.*	
10.70	Unbleached	550	5 C	4	4	77		
	¾ oz. Beta Chlora	510	9	4	4	86	−40	− 9
	1½ oz. Beta Chlora	510	8 c	3 p	4	82	−40	− 5
	2¼ oz. Beta Chlora	500	6 c, o	1 v.p	2 v.o	71	−50	− 6
11.90	Unbleached	550	8	4	3 g	86		
	3¾ oz. Beta Chlora	530	9	4	4	88	−20	− 2
	1½ oz. Beta Chlora	530	7 C	3 p	3 o	80	−20	− 6
	2¾ oz. Beta Chlora	490	6 c, o	1.5 v.p	2 v.o	71	−60	−15
12.40	Unbleached	520	8	4	3 g	83		
	¾ oz. Beta Chlora	480	8	2 p	3 o	77	−40	− 6
	1½ oz. Beta Chlora	530	7 c	2 p	3 o	79	−10	− 4
	2¼ oz. Beta Chlora	470	7 c	3 p	4 o	78	−50	− 5
13.50	Unbleached	570	7 C	5	4	87		
	¾ oz. Beta Chlora	530	9	5	4	89	−40	− 2
	1½ oz. Beta Chlora	560	8	5	4	89	−10	− 2
	2¼ oz. Beta Chlora	460	8	3 p	3 o	76	−110	−11
14.20	Unbleached	590	7 C	4	3 g	87		
	¾ oz. Beta Chlora	600	8	5	5	94	−10	− 7
	1½ oz. Beta Chlora	580	9	5	4 o	94	−10	− 7
	2¼ oz. Beta Chlora	550	8	4	4 o	87	−40	0
15.30	Unbleached	640	6 C	3 p	3 g	88		
	¾ oz. Beta Chlora	650	8	4	5	98	−10	−10
	1½ oz. Beta Chlora	650	9	5	5	102	−10	−14
	2¼ oz. Beta Chlora	600	8 c	4.5	4 o	93	−40	− 5

TABLE IV

POTASSIUM BROMATE SERIES

Protein content of flour	Treatment	Loaf volume	Texture and grain	Crust color	General appearance	Computed baking score	Response to treatment	
							Loaf volume	Baking score
P.ct.		*Cc.*	*Score*	*Score*	*Score*		*Cc.*	
	Unbleached	550	5 C	4	3 g	77	—	—
	1 mg. $KBrO_3$	510	7	4	5	81	−40	+ 4
10.70	2 mg. $KBrO_3$	500	5 c	3 p	4	72	−50	− 5
	3 mg. $KBrO_3$	480	6 c	2 p	3 o	71	−70	− 6
	4 mg. $KBrO_3$	470	5 c	1 p	2 o	65	−80	−12
	Unbleached	550	8	4	3 g	86	—	—
	1 mg. $KBrO_3$	580	9	4	4	93	+30	+ 7
11.90	2 mg. $KBrO_3$	580	9	5	4	94	+30	+ 8
	3 mg. $KBrO_3$	540	9	3 p	3 o	87	−10	+ 1
	4 mg. $KBrO_3$	520	7	2	2	74	−30	−12
	Unbleached	520	8 C	4	3 g	83	—	—
	1 mg. $KBrO_3$	610	8	5	5	95	+90	+12
12.40	2 mg. $KBrO_3$	530	9.5	5	4	92	+10	+ 9
	3 mg. $KBrO_3$	530	9	4	4	88	+10	+ 5
	4 mg. $KBrO_3$	490	8	3 p	3 o o	79	−30	− 4

TABLE IV—*Continued*

Protein content of flour	Treatment	Loaf volume	Texture and grain	Crust color	General appearance	Computed baking score	Response to treatment	
							Loaf volume	Baking score
P.ct.		*Cc.*	*Score*	*Score*	*Score*		*Cc.*	
	Unbleached	570	7 C	5	4	87	—	—
	1 mg. $KBrO_3$	670	8	4	3	98	+100	+11
13.50	2 mg. $KBrO_3$	650	8	4	4	97	+80	+10
	3 mg. $KBrO_3$	650	9	5	4	101	+80	+14
	4 mg. $KBrO_3$	620	8	5	4	95	+50	+ 8
	Unbleached	590	7 C	4	3 p	87	—	—
	1 mg. $KBrO_3$	630	8	5	4	96	+40	+ 9
14.20	2 mg. $KBrO_3$	670	9	5	5	104	+80	+17
	3 mg. $KBrO_3$	650	9	5	5	102	+60	+15
	4 mg. $KBrO_3$	670	9	5	4 o	102	+80	+15
	Unbleached	640	6 C	3 p	3 g	88	—	—
	1 mg. $KBrO_3$	710	8	4	4 g	103	+70	+15
15.30	2 mg. $KBrO_3$	700	8.5	5	5	106	+60	+18
	3 mg. $KBrO_3$	670	9	5	4.5	104	+30	+16
	4 mg. $KBrO_3$	680	9.5	5	5	107	+40	+19

scored on a numerical basis in the manner discussed by Geddes (1930). The following factors were considered in scoring the loaves and in assigning the key letters which indicate the type of fault for which any loaf was scored down:

Grain and texture (considered together), perfect score = 10
C = coarse
c = close
o = open
Crust color, perfect score = 5
p = pale
d = dark
General appearance, perfect score = 5
g = green or underfermented
o = old or overfermented

The final baking score was arrived at as follows:

Sum of loaf volume × 0.1 .....
Score for texture × 3 .....
Score for crust color × 1 .....
Score for appearance × 1 .....

Computed baking score .....

It is true that this method of scoring is empirical, but it was felt that in a study of this kind loaf volume alone would in many cases lead to faulty conclusions. The scoring method was adopted as being the best suited to the present study of any of the scoring methods so far published. It will be seen later in the discussion that even in this study it did not take into consideration some of the important characteristics of the doughs from the different samples.

Tables II and III, and Figures 1 and 2 summarize the results obtained by baking the flours on the day after bleaching. Table IV presents the results obtained by adding $KBrO_3$ to the formula, using the unbleached flours. In order to have the curves for the three treatments, Agene, Beta Chlora, and $KBrO_3$, for each sample of flour on one diagram, the dosages of each reagent were plotted on the same ordinates. This should not be interpreted to mean that the treatments were *equal* in their effect, but only that it shows that the three reagents were *relatively similar* in their effect.

In all cases the unbleached flours possessed the characteristics of slightly green flour. The addition of all three reagents aged the flour, so that at the higher dosages the loaves appeared old or overfermented. The flours of low protein content were over-aged by relatively small amounts of reagent, while the higher protein flours were improved in handling quality, loaf volume, and baking score until the amounts of reagent used were comparatively high—after which signs of age or overfermentation appeared.

The computed baking scores would not be wholly satisfactory to

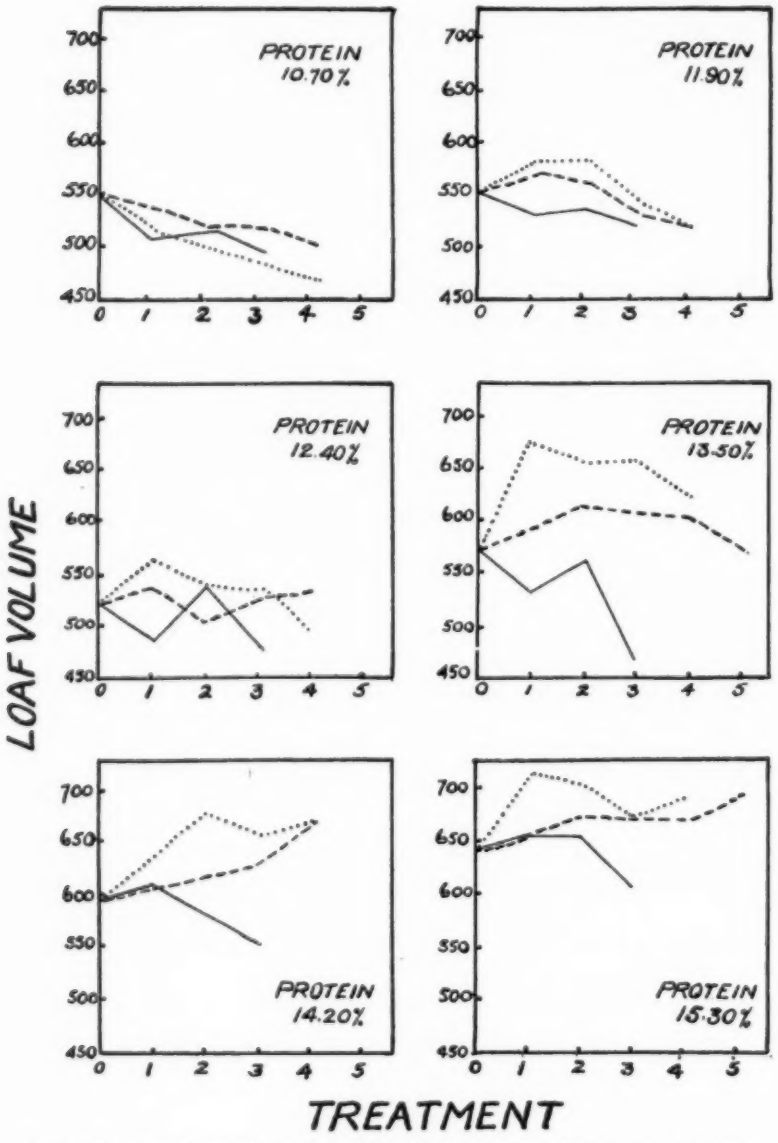

Fig. 1. The effect of maturing agents on loaf volume of flours of different protein contents.
— — — — Agene
. . . . . $KBrO_3$
———— Beta Chlora.

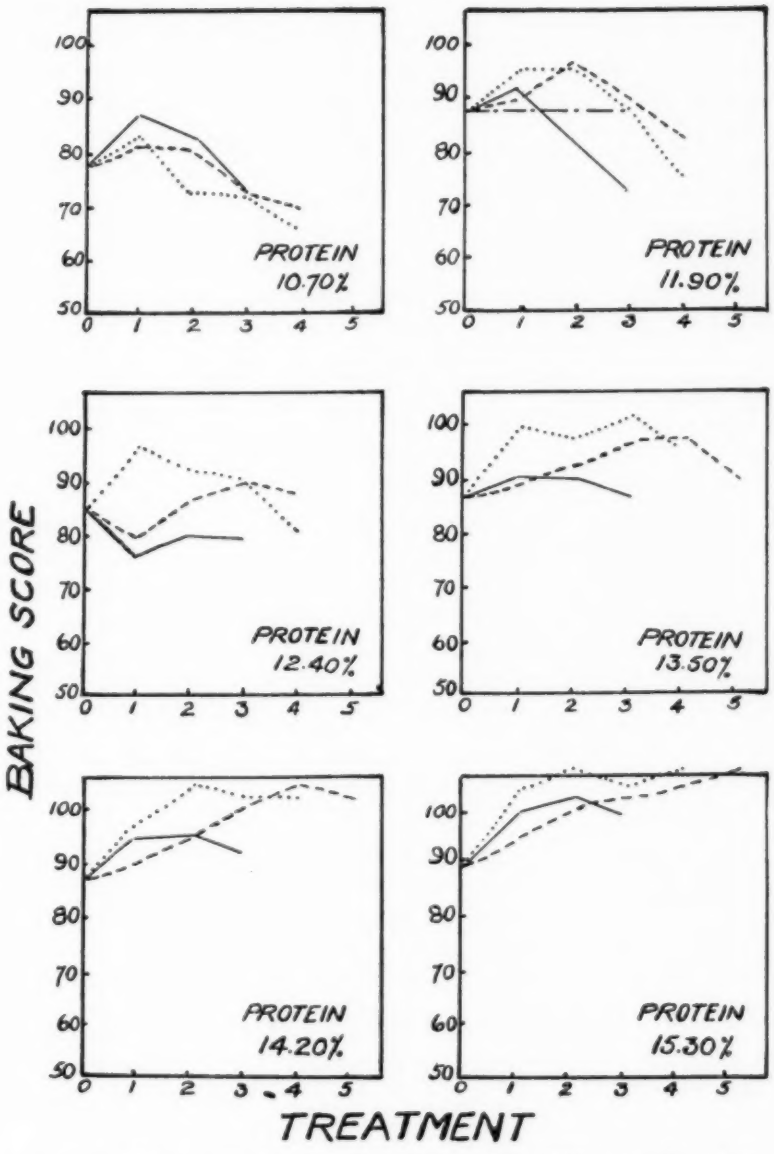

Fig. 2. The effect of maturing agents on baking score of flours of different protein contents.
— — — — Agene
. . . . . $KBrO_3$
———— Beta Chlora.

the commercial baker because they do not include any estimates of the handling qualities of the doughs. In general, the doughs "tightened up" and became livelier as the dosage increased. This effect increased as fermentation progressed so that with flours of medium protein content, and with the higher dosages of reagent, the doughs were difficult to mold for panning. This characteristic should lower the scores somewhat for the higher dosages of reagent. In the case of the higher protein flours, the doughs from the untreated flours were tough and appeared very much undeveloped and "gluten bound." They became full of large bubbles and the gas was very difficult to "punch out." The scores for these loaves should consequently be lower than recorded. The addition of all three reagents progressively improved the handling qualities of these flours, making the doughs more elastic. The characteristics of overaging did not appear until comparatively large dosages were employed. In the case of the flours of lowest protein content the doughs were putty like and although all three reagents made them somewhat more lively, the effect was hardly significant. On account of the poor handling qualities of these flours the scores for the loaves from them should rightly be lower than reported.

It should be noted that no scores were included for absorption. This was partly because of the difficulty of determining accurately the correct absorption of the doughs with the experimental baking test. The addition of Agene and $KBrO_3$ increased the absorption as much as two or three per cent. Beta Chlora apparently did not have as much effect in this respect. Absorption is an important characteristic to the commercial baker and he therefore would score those flours with greater absorption higher.

The Agene treated flours were again baked after storing in tight containers for one month. The flours of lowest protein content deteriorated both in texture and loaf volume, in the case of the bleached as well as the unbleached samples. With the flours of higher protein content there was an improvement in baking qualities of the unbleached flours and a slight increase in quality of the bleached samples.

It is important to note also that the doughs matured with Beta Chlora did not "tighten up" to the same extent as the Agene and $KBrO_3$ series, although the loaves showed the same signs of age with the higher dosages. This was very probably due to the softening of the gluten by the increase in hydrogen-ion concentration due to the chlorine content of the maturing reagent.

The action of $KBrO_3$ on the doughs appeared to be the same as that of Agene. The doughs handled very much the same and the loaves had the same characteristics. $KBrO_3$ appeared to have a greater effect on

loaf volume, as greater volumes were obtained than could be obtained with either Agene or Beta Chlora.

All three reagents are powerful oxidizing agents. Their action may, then, have its explanation in a process of oxidation. It is obvious that such minute amounts that are necessary for satisfactory maturation cannot effect gross chemical changes. Their effect, therefore, must be a colloidal one.

Table V summarizes some of the chemical and physico-chemical measurements made on the treated and untreated flours. As other investigators have pointed out, there was no significant increase in the titratable acidity of the Agene treated flours, even when the amount of reagent used was comparatively high. Flours treated with Beta Chlora increased in acidity as the dosage increased. This was probably due to the chlorine content of the reagent. As apparatus was not available, no measurements of hydrogen-ion concentration could be made.

Agene did not increase the amount of proteins " soluble " in distilled water. There was a significant increase with the Beta Chlora series. The peptizability of the proteins by $MgSO_4$ solution was determined by the method described by Rich (1933). Agene treatment did not increase the peptizability of the proteins.

Sharp and Gortner (1923) and others have discussed the influence of hydration capacity of the proteins on baking quality. Viscosity measurements made by the method described by Rich (1932) indicated that there was a slight increase in this characteristic with the higher amounts of Agene. It is probable that this increase of hydration capacity is associated only with the higher water absorption of the flours. The greater amounts of Beta Chlora slightly lowered the viscosity measurements. It should be noted that the doughs from this series did not tighten up to the same extent as did the Agene series of flours, and therefore did not possess as high absorption. The lowering of the viscosity measurements of the Beta Chlora series may have been due to the increase in hydrogen-ion concentration of the flours caused by the chlorine content of the reagent.

Although not given here in detail, there was no significant change in ash content, total proteins, etc., due to treatment with either reagent.

Although the physico-chemical measurements of protein quality used showed no change in the inherent colloidal properties of the *proteins*, by artificial maturation with nitrogen trichloride there was a decided improvement in the quality of the *glutens*, which was shown by the sense of feel of the washed gluten. In each series the washed gluten from the unbleached flours was slightly soft. Agene improved the elasticity of the gluten making it stronger and more lively. With those flours in which the baking test indicated overbleaching, the gluten could

be described as "tough elastic." There were no signs of shortness or deterioration. Beta Chlora produced very much the same effect on the gluten as Agene, as far as could be determined by the sense of feel of the washed gluten.

TABLE V

ANALYTICAL DATA OBTAINED FROM EXPERIMENTALLY MILLED FLOURS

Viscosity of Flour-in-Water Suspensions

Treatment	Protein content—*P.ct.*					
	10.70	11.90	12.40	13.50	14.20	15.30
Unbleached	43	52	68	104	116	124
2 gm. Agene per barrel	41	58	64	—	—	—
4 gm. Agene per barrel	43	64	71	103	118	138
6 gm. Agene per barrel	43	70	71	103	120	138
8 gm. Agene per barrel	42	80	66	100	123	140
10 gm. Agene per barrel	—	—	—	100	122	138
Unbleached	43	52	68	104	116	124
¾ oz. Beta Chlora per barrel	44	56	67	110	118	132
1½ oz. Beta Chlora per barrel	42	58	65	98	118	132
2¼ oz. Beta Chlora per barrel	40	64	66	93	114	130

Per cent Protein "Soluble" in N/2 $MgSO_4$ Solutions

Treatment	Protein content—*P.ct.*					
	10.70	11.90	12.40	13.50	14.20	15.30
Unbleached	2.45	2.47	2.47	2.59	2.59	2.63
2 gm. Agene per barrel	2.43	2.47	2.47	—	—	—
4 gm. Agene per barrel	2.47	2.43	2.31	2.59	2.63	2.63
6 gm. Agene per barrel	2.43	2.43	2.47	2.59	2.59	2.59
8 gm. Agene per barrel	2.43	2.47	2.47	2.51	2.59	2.63
10 gm. Agene per barrel	—	—	—	2.59	2.63	2.63
Unbleached	2.45	2.47	2.47	2.59	2.59	2.63
¾ oz. Beta Chlora per barrel	2.45	2.45	2.39	2.55	2.59	2.63
1½ oz. Beta Chlora per barrel	2.45	2.43	2.47	2.55	2.63	2.63
2¼ oz. Beta Chlora per barrel	2.43	2.47	2.51	2.51	2.63	2.59

Per cent Protein "Soluble" in Distilled Water

Treatment	Protein content—*P.ct.*					
	10.70	11.90	12.40	13.50	14.20	15.30
Unbleached	2.43	2.43	2.63	2.83	2.83	2.99
2 gm. Agene per barrel	2.43	2.31	2.63	—	—	—
4 gm. Agene per barrel	2.47	2.43	2.83	2.83	3.07	3.19
6 gm. Agene per barrel	2.55	2.47	2.99	3.23	3.07	3.19
8 gm. Agene per barrel	2.47	2.55	3.07	3.07	3.19	3.19
10 gm. Agene per barrel	2.55	2.55	3.07	3.23	3.23	3.27
Unbleached	2.43	2.43	2.63	2.83	2.83	2.99
¾ oz. Beta Chlora per barrel	2.43	2.43	2.67	3.39	3.33	3.39
1½ oz. Beta Chlora per barrel	2.57	2.83	3.19	3.39	3.39	3.39
2¼ oz. Beta Chlora per barrel	2.67	2.99	3.27	3.47	3.47	3.47

TABLE V—*Continued*

Treatment	Titratable Acidity					
	Protein content—*P.ct.*					
	10.70	11.90	12.40	13.50	14.20	15.30
Unbleached	.150	.155	.160	.155	.160	.155
2 gm. Agene per barrel	.150	.155	.160	.155	.160	.155
4 gm. Agene per barrel	.165	.160	.160	—	—	—
6 gm. Agene per barrel	.160	.160	.160	.160	.165	.165
8 gm. Agene per barrel	.160	.160	.165	.165	.165	.170
10 gm. Agene per barrel	—	—	—	.170	.170	.160
Unbleached	.150	.155	.160	.155	.160	.155
¾ oz. Beta Chlora per barrel	.170	.175	.165	.175	.180	.175
1½ oz. Beta Chlora per barrel	.200	.205	.200	.210	.215	.210
2¼ oz. Beta Chlora per barrel	.220	.215	.215	.230	.230	.225

Bailey (1916) suggested that "the strength of flour is determined by the ratio between the rate of production in, and the rate of loss of carbon dioxide from the fermenting doughs." The gas-producing and the gas-retaining capacity of the doughs were determined in an apparatus similar to that described by Bailey and Johnson (1924). Doughs were made according to the formula of the baking test and placed in the apparatus. It was found that the rate of gas production was practically the same for all of the flours of both series. The several pages of data are too lengthy to include but, in general, the smaller amounts of Agene and Beta Chlora influenced the flours so that the gas did not begin to escape from the doughs as soon as it did from the unbleached flours, nor did as much escape from the dough. When the amount of maturing agent exceeded the maximum for a satisfactory loaf, the escape of gas began much earlier, and less gas was held, making the dough mass small. From the data obtained it was evident that artificial maturation had no influence on gas production, but increased the gas retention capacity of the doughs, until an excess of reagent was used, when the gas retention capacity was impaired very soon after fermentation began. Then the reduction in gas retention was greater than for the untreated flour. The measurements gave no indication as to why there was a difference in gas retention between untreated, satisfactorily treated, and over-treated flours. Further experiments were, therefore, undertaken to clarify this point.

The Lipoid Content of Flours in Relation to Dough and Bread Characteristics

The present methods of determining differences in the inherent quality of wheat flour proteins fail to show any changes due to artificial maturation with nitrogen trichloride. On the other hand, the "feel"

of the washed gluten, the handling properties of the fermenting dough, and the appearance of the baked loaf all indicate that there is a decided improvement due to the action of artificial maturing agents. This suggests that the modification of the baking qualities of flour is due to some indirect effect on the proteins.

The proteins in a dough are in a colloidal state, and thus will be profoundly influenced by any change in the environment formed by the complex constituents of the dough. Working (1924, 1928, 1928a) expressed the view that the lipoids normally present in flour influence the properties of the gluten very markedly. He found that prolonged washing of the gluten from a low grade flour removed the phosphatides and at the same time gradually increased the tenacity of the gluten until it became practically equivalent to gluten from a patent flour. On the other hand, adding lethicin or wheat phosphatide to patent flour decreased the elasticity of the gluten until it became similar to gluten from low grade flour.

Sullivan and Near (1927, 1927a, 1928) found that the gluten from patent flour was lowest in lipoid content, while clear flours were highest. They pointed out that this was in the reverse order to gluten quality. Salamon (1908), Winton (1911), Mohs (1924), Johnson (1928), Geddes (1930), Johnson and Whitcomb (1931) found that in most cases the removal of ether soluble substances from flours improved their baking qualities. Recent work of Martin and Whitcomb (1932) demonstrated that apparently this does not hold true in all cases, as some of their flours were not improved by ether extraction. Johnson and Whitcomb (1931) showed that the gas retaining power of the doughs made from their ether extracted flours was significantly greater than that of the non-extracted flours. They also found that the addition of lard to extracted flour did not reduce the baking quality to that of the unextracted flour, and concluded that ether soluble substances other than the true glycerides were responsible for the impairment of gas retaining capacity. They showed that clears and low grade flours were improved by ether extraction more than the highly refined middlings flour. Geddes (1930) states that "the green or underfermented appearance was greatly reduced by ether extraction and the loaves had a bolder appearance with good break and shred. Texture was markedly improved."

Swanson, Willard, and Fitz (1915), Smith and Bailey (1923), Kent-Jones (1924) and others have demonstrated by ether extraction that the total lipoid content of flour increases with lowering of the flour grade.

The lipoids of the wheat kernel are found mainly in the embryo. The cells of the aleurone layer also contain a small proportion of the

total lipoids. It is quite probable that the endosperm contains very little of this material. Undoubtedly the lower grade mill stream flours are more contaminated with germ, which accounts for their higher lipoid content. Examination of the separations made by the purifiers and bolters in the mill show small germ particles in all of the separations from the first break separations to the tailings streams. Geddes (1930) found that the addition of "raw" germ to a highly refined flour markedly reduced its baking qualities, as reflected in poorer handling qualities of the dough, decrease in loaf volume, underfermented appearance of the loaf, and coarse open texture. Increasing the fermentation time, the addition of an oxidizing agent, or heating the germ before admixture reduced the deleterious effects of the germ.

While the evidence so far published is largely indirect, it suggests that the change due to oxidizing agents (*e.g.*, $KBrO_3$), heat treatment, artificial maturing, and natural aging might be found to center around changes in certain germ constituents, presumably the phosphatides.

In view of the fact that the action of artificial maturing agents is apparently not a direct action on the colloidal properties of the proteins of wheat flour, work was undertaken to determine whether the maturing effect might be attributed to changes in the germ constituents of the flour. A high grade mill stream flour (first middlings flour) was first chosen, but on account of its low protein content, the response to treatment was low. Following the lead of Geddes (1930), fifth middlings flour was chosen for subsequent tests.

TABLE VI

ILLUSTRATING THE INFLUENCE OF GERM ON MIDDLINGS FLOUR AND THE IMPROVEMENT IN BAKING QUALITIES DUE TO THE ACTION OF MATURING AGENTS

Treatment	Loaf volume	Grain and texture	Crust color	Appearance	Baking score
	Cc.	*Score*	*Score*	*Score*	
5th middlings flour (control)	570	9	5	5	94
Control plus 3 gms. Agene per barrel	620	10	5	5	102
Control plus 0.001% $KBrO_3$	650	9.5	5	5	104
Control plus 5% germ	590	4 C	3 d	2.5 g	77
Agene bleached control (3 gms.) plus 5% germ	650	4 C	3 d	2.4 g	83
Control flour plus germ mixture, bleached with Agene (3 gms.)	640	8	4.5	4.5	97
Control flour plus germ mixture, plus 0.001% $KBrO_3$	670	9	4.5	4.5	104
Control flour plus bleached germ	550	9	4.5	5	91
Control flour plus heated germ	630	8.5	5	4	98

This flour had an ash content of 0.38% and was high enough in protein content (13.50%) to obtain significant responses to the treatments given. Freshly milled germ was pulverized on the laboratory grinder. The bran chips with which it was contaminated pulverized less easily and were largely removed by sifting. The pulverized germ was added to the control flour (fifth middlings flour) in the proportion of 5% germ to 95% flour. Fresh germ was used and was added just before baking. A series of samples was treated as indicated in Table VI. The results of baking are also summarized in the table.

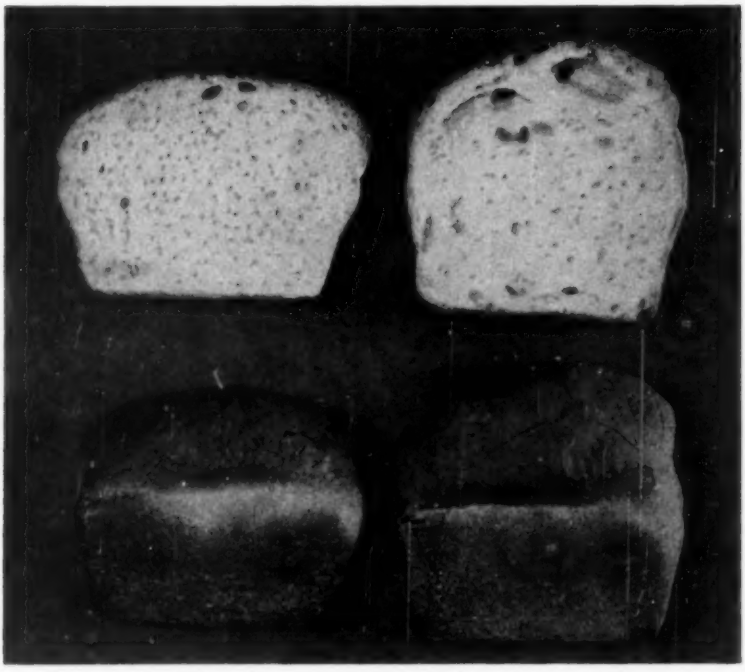

Fig. 3. Fifth middlings flour, untreated and bleached with Agene at the rate of 3 grams per barrel.

By bleaching fifth middlings flour with Agene at the rate of 3 gms. per barrel, or by adding 0.001% $KBrO_3$ its baking quality was slightly increased. This was evident in the slighly better handling quality of the dough, better oven spring, greater loaf volume, and by slightly better texture. See Figure 3.

The addition of 5% of "raw" pulverized germ to fifth middlings flour, either unbleached or bleached with Agene, markedly decreased the baking quality of the flour. The doughs were somewhat sticky when mixed. However, they improved as fermentation progressed. The

loaves exhibited pronounced characteristics of a green or underfermented dough, namely, flat top, glossy sides with sharp corners and no break. The texture of the crumb was coarse and open. (Figure 4.)

When the germ-flour mixture was treated with Agene at the rate of 3 gms. per barrel, or was baked with 0.001% $KBrO_3$, there was a marked response in regard to handling qualities of the dough, loaf volume, general appearance, and texture. The doughs tightened up so that they resembled the doughs from the untreated control flour. See Figure 4.

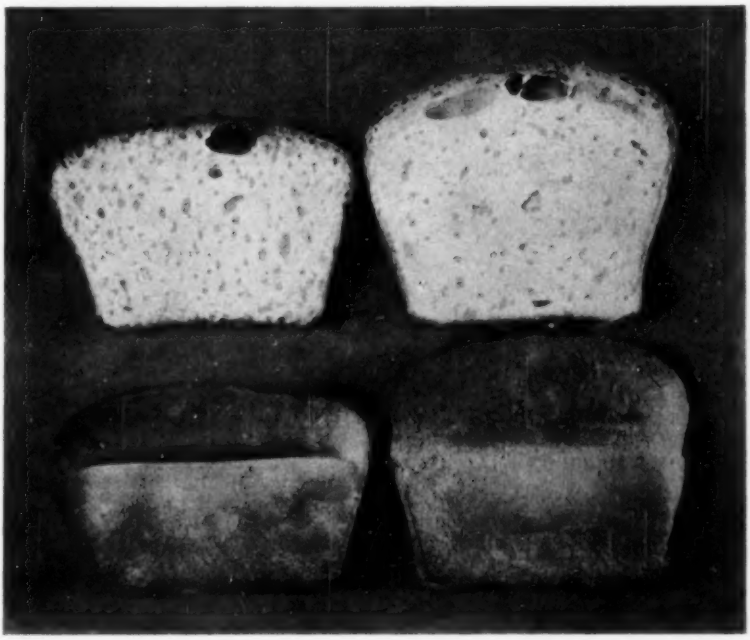

Fig. 4. The effect of adding 5% of pulverized germ to a fifth middlings flour, untreated and bleached with Agene at the rate of 3 grams per barrel.

An attempt was made to bleach pulverized germ at such a rate that when added to the control flour the flour would have a dosage of 4 gms. per barrel. On account of the small amount of germ in the bleaching chamber, the reaction was probably incomplete, but the addition of the germ thus treated to the control flour produced loaves similar to those in which the germ-flour mixture was bleached. Likewise, heated germ added to the control flour did not have the deleterious effects of raw germ.

These experiments indicate that the maturing action of nitrogen trichloride (Agene) depends primarily on some reaction with the germ

content of the flour. The similar effect of $KBrO_3$ suggests that the action is one of oxidation.

The work of former investigators has suggested that the lipoids of the germ are the constituents responsible for the poorer baking qualities of the low grade flours. Extracting the lower grade flours with ether has been found by most investigators to improve the baking qualities of flour. Vice versa, adding the ether extract of germ should have a detrimental effect on the baking quality of a high grade flour. To determine whether this is true, 5 gms. of fresh germ were extracted for 16 hours

TABLE VII

ILLUSTRATING THE INFLUENCE OF ETHER EXTRACT OF GERM ON THE BAKING QUALITIES OF FIFTH MIDDLINGS FLOUR, AND OF THE INFLUENCE OF EXTRACTED GERM ON BAKING QUALITIES

Treatment	Loaf volume	Grain and texture	Crust color	Appearance	Baking score
	Cc.	*Score*	*Score*	*Score*	
Control flour	570	9	5	4.5	94
Control plus 5% germ	550	4 C, o	4 d	2.5 g	74
Control plus 5% germ bleached with Agene (3 gms.)	590	9.5	5	5	98
Control plus 5% germ plus 0.001% $KBrO_3$	650	9.5	5	5	103
Control plus ether extract	590	9	4.5	4.5	95
Control plus ether extract plus 0.001% $KBrO_3$	640	10	5	5	104
Control plus ether residue	450	3 C, o	4	2.5 g	62
Control plus ether residue plus 0.001% $KBrO_3$	530	7 C	4	4	82

with anhydrous ether and the extract, after the ether had been gently evaporated, was added to the control flour at the time of mixing the dough. For comparison, the residue was also added to another sample of the flour. On account of it being necessary to add the ether extract at the time of mixing, $KBrO_3$ was used instead of Agene. The results which are the average of several closely agreeing duplicate tests are given in Table VII.

From the above data it is evident that the ether soluble portion of the germ was not responsible for the detrimental properties of wheat germ. However, according to MacLean (1918) the phosphatides are not completely soluble in pure ether although they are partially so when other fats are present. For complete extraction of the phosphatides he recommends a preliminary extraction with ethyl alcohol and a final extraction with pure ether. Rask and Phillips (1925) recommend their ammoniacal-alcohol method for complete extraction. Accordingly, freshly milled germ was extracted according to the methods described by Mac-

Lean (1918) and by Rask and Phillips (1925). The extracts from 5 gms. of germ were added to the control flour at the time of mixing of the dough. Flours containing the ether residues were also baked. The results are shown in Table VIII and are similar to those obtained with the simple ether extracts.

TABLE VIII

THE EFFECT OF GERM EXTRACT AND OF EXTRACTED GERM ON THE BAKING QUALITIES OF FIFTH MIDDLINGS FLOUR

Treatment	Loaf volume	Grain and texture	Crust color	Appearance	Baking score
	Cc.	*Score*	*Score*	*Score*	
MacLean's (1918) method					
Control plus extract	570	9.5	4.5	4.5	93
Control plus extract, plus 0.001% $KBrO_3$	620	8	5	5	96
Control plus residue	480	3.5 C, o	4 p	2.5 g	65
Control plus residue, plus 0.001% $KBrO_3$	590	7.5	4.5	5	92
Rask and Phillips' (1925) method					
Control plus extract	450	3 C, o	5	4.5 g	96
Control plus extract, plus 0.001% $KBrO_3$	620	9	5	5	99
Control plus residue	560	4.5 C, o	4.5	3 g	77
Control plus residue, plus 0.001% $KBrO_3$	590	8	4.5	4.5	92

Table IX summarizes the results obtained by adding soybean oil, egg yolk, and wheat-germ oil (alcohol-ether extract) which all contain phosphatides, to the control flour in various amounts. In all cases there was an improvement in baking qualities, even when comparatively large amounts were used. There is also attached data obtained by adding wheat germ oil to a first clear flour. The oil improved the characteristics of the unbleached "green" first clear flour, and had very little effect on the artificially matured sample.

It is interesting to note that the eighth annual report of the Research Association of British Flour Millers (abstracted by the Canadian Milling and Grain Journal, 1932) contains the results of some similar experiments. With an extraction apparatus which had a capacity of sixty pounds of flour, the oil of wheat flour was extracted with ether and the lipins with alcohol. This enabled them to conduct tests on a full sized bakeshop. It was found that neither the oils nor the lipins were factors of lowgradeness; on the contrary, as in the present study, both the ether and the alcohol extracts improved the flours to which they were added.

It is difficult to explain the differences between results of the present study (and that of the British Flour Millers Association) and the data of other investigators who examined ether extracted flours. It is quite

possible that the action of ether on the flour itself may have a beneficial effect, which effect would not occur in the natural course of milling. Further study of this is projected.

TABLE IX

THE EFFECT OF ADDING VARIOUS AMOUNTS OF WHEAT-GERM OIL, SOYBEAN OIL, AND EGG YOLK TO FIFTH MIDDLINGS AND CLEAR FLOUR

Treatment	Loaf volume	Grain and texture	Crust color	General appearance	Baking score
	Cc.	*Score*	*Score*	*Score*	
Control (fifth middlings) flour	550	8.5	5	5	91
5M[1] plus 1 mg. $KBrO_3$	600	9.5	5	5	99
5M plus 0.5% germ oil	630	8.5	5	5	103
ditto, plus 1 mg. $KBrO_3$	650	9.5	5	5	105
5M plus 1.0% wheat-germ oil	650	9.5	5	5	101
ditto, plus 1 mg. $KBrO_3$	650	9	5	5	104
5M plus 2.0% wheat-germ oil	650	9.5	5	5	104
ditto, plus 1 mg. $KBrO_3$	660	9	5	5	103
5M plus 1.0% egg yolk	690	10	5	5	109
ditto, plus 1 mg. $KBrO_3$	750	10	5	5	115
5M plus, 2.0% egg yolk	700	10	5	5	110
ditto, plus 1 mg. $KBrO_3$	760	10	5	5	116
5M plus 3.0% egg yolk	720	9	5	5	108
ditto, plus 1 mg. $KBrO_3$	790	9	5	5	115
5M plus 0.7% soy oil	570	9	5	4 g	93
ditto, plus 1 mg. $KBrO_3$	700	8	5	5	104
5M plus 1.0% soy oil	600	8	5	5	97
ditto, plus 1 mg. $KBrO_3$	690	8.5	5	5	105
5M plus 2.0% soy oil	610	8.5	5	5	97
ditto, plus 1 mg. $KBrO_3$	730	8	5	5	107
First clear flour	620	3 C, o	4 d	2 g	77
ditto, plus 0.5% germ oil	670	5 C	4 d	4	90
ditto, plus 2.0% germ oil	720	6 C	4 d	4	98
First clear bleached with Agene, 4 gms. per barrel	740	7 C	4 d	5	104
ditto, plus 1 mg. $KBrO_3$	740	7 C	4 d	5	104

[1] 5M = fifth middlings flour.

The Relation of Germ Content to Flour Maturation

It is known that the reaction to oxidizing agents or the improvement due to natural aging is greater the lower the grade of the flour. The experiments on the effect of germ suggest that the chief factor for these differences may be ascribed to the greater germ contamination of the lower grades of flour.

Simon (1930) held the belief, and he is not alone in this stand, that the increase in ash content, which is associated with decrease in baking quality of mill stream flours, is due to contamination of the endosperm with bran pulverized by the machines during the milling process. According to this theory, clear flours with an ash content of 0.75% contain about 8% of pulverized bran.

To test the validity of this hypothesis, bran was pulverized in the laboratory grinder to pass through a 10XX silk sieve. The resultant powder was soft and resembled Portland cement in appearance. The control flour containing this powder was of a brown color, quite different in appearance to low grade flour. Mixtures of the control flour with 5% of bran powder were bleached with Agene at the rate of 3 gms. per barrel. Bleached and unbleached samples of the bran powder-flour mixture were baked. The results are summarized in Table X. For comparison, the germ-flour mixture data are also given.

TABLE X

THE EFFECT OF PULVERIZED GERM AND OF PULVERIZED BRAN ON THE BAKING QUALITIES OF FIFTH MIDDLINGS FLOUR

Treatment	Loaf volume	Grain and texture	Crust color	Appearance	Baking score
	Cc.	*Score*	*Score*	*Score*	
Control flour	570	9	5	5	94
Control bleached (3 gms. Agene per barrel)	620	10	5	5	102
Control plus bran powder	570	9	5[1]	4	93
Control plus bran powder bleached (3 gms. Agene)	500	8	4[1]	3 o	81
Control plus germ powder	590	4	3 d	2.5 g	77
Control plus germ powder bleached (3 gms. Agene)	640	8	4.5	4.5	97
First clear flour	620	3 C, o	4 d	2 g	77
First clear flour bleached (3 gms. Agene)	740	7 C	4 d	5	104

[1] Crust color masked by bran.

The germ-flour mixture resembled the first clear flour in the baked loaf. (See Figures 4 and 5.) The first clear flour was soft in the dough but was not as sticky as the germ-flour mixture. After bleaching with Agene the response from the first clear and the germ-flour mixture was almost parallel. The loaf volume was increased, the texture was improved, and the green appearance of the loaf disappeared. The doughs were also much tighter and stronger.

The addition of pulverized bran to the control flour did not produce a mixture in any way resembling a clear flour. The dough tightened up as fermentation progressed, instead of remaining soft. The finished

loaf showed signs of greater age than the control. (See Figure 6.) The texture was not significantly impaired. Bleaching with Agene at the rate of 3 gms. per barrel caused the flour to produce a loaf which showed the characteristics of a greatly over-matured flour, as was indicated by the "bucky" dough, close texture, gnarled sides, rounded edges, etc., of the loaf. Although this study does not deal with changes in color of crumb, it is interesting to note that the crumb of the germ flour mixtures resembled the first clear in both the bleached and unbleached samples. The crumb of the bran-flour mixtures was brown and more closely resembled whole wheat flour than a first clear. This was true also of the color of the flours themselves.

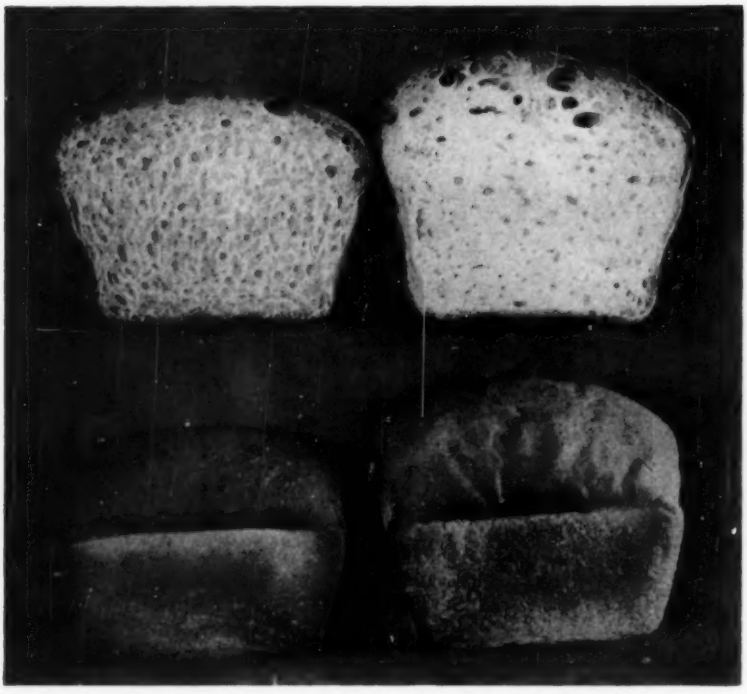

Fig. 5. Clear flour, untreated and bleached with Agene at the rate of 3 grams per barrel.

In the milling process the first break rolls liberate the germ from most of the wheat kernels, although a few remain attached to be broken loose during the second break. Examination of the stock with a magnifying glass shows that while most of the germs or embryos have not been broken, there are some that have been fractured and are in several pieces. The separations which are made after the first scalp is removed are classified according to their dimensions and any particles of

germ of corresponding size will be included in each classification. The first classification after the scalp goes to a purifier. This contains most of the embryos that have not been subjected to pressure. The purifier (which separates the particles according to their specific gravity) does not remove germ particles from the same size middlings, and therefore germ particles will be included in each classification from the first purifier. However, in this case most of the germ particles will be included in the stream which goes to the sizings roll. The smaller particles from

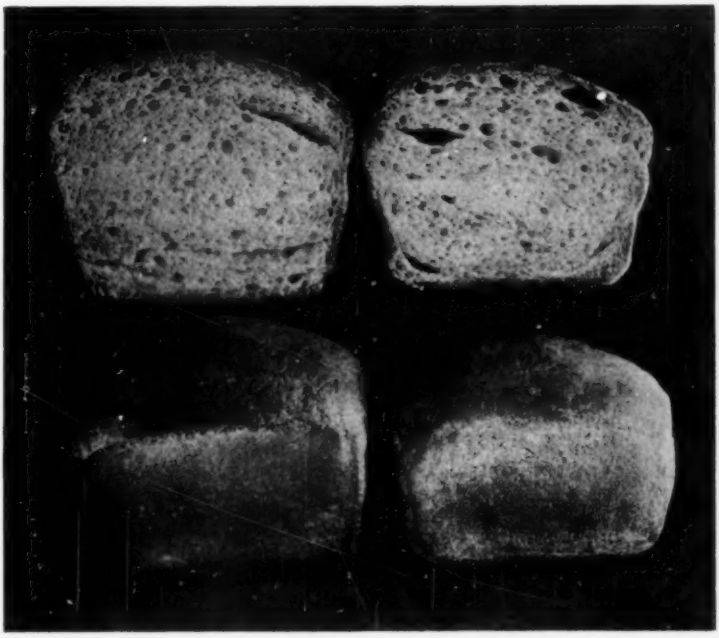

Fig. 6. The effect of adding 5% of pulverized bran to a fifth middlings flour, untreated and bleached with Agene at the rate of 3 grams per barrel.

first and second break are found in the classifications going to first middlings roll. After being subjected to the sizings roll, the germ is partially flattened and is scalped off and from there goes to either the tailings roll or to the fifth break according to the flow of the mill. The scalp or tailings from the first purifiers contain some germs or pieces of germ and thus contaminate the third or fourth break stocks. All of the classifications from the sizings roll contain a considerable amount of broken germ, in fact, examination of all of the coarser separations of all of the subsequent purifiers and bolters shows small germ particles, and though visible particles cannot be seen in the flour streams it is reasonable to suppose that if germ particles are visible in the coarser

separations of the same bolters, that smaller particles must also be present in the flour. The analyses published by Swanson, Willard, and Fitz (1915), Bailey (1925), and Kent-Jones (1924) of the fat content of mill streams indicate that such a supposition is very probably correct.

Anyone who has tried to grind dry bran to a powder which will pass through a 10XX silk sieve will question the hypothesis that the milling machines produce enough of this powder from tempered bran to raise the ash content to that of the clear and low grade flours. On the other hand, germ is comparatively easily broken, particularly when it loses part of its moisture and fat content which happens during the milling process. As ether extraction data indicate, germ does contaminate the mill streams, increasing in amount as the tail of the mill is approached.

Baking tests indicate that bran powder is not responsible for the decreased baking quality of the lower grade mill streams and that changes induced in the bran powder are not responsible for the marked improvement of the lower grade flours due to artificial maturing or to other oxidizing agents. In fact, the addition of bran powder is opposite in its effect. The addition of pulverized germ produced a loaf that closely resembled the lower grades of flour—the baking quality decreasing as the proportions of germ increased, and the response of the mixtures to maturing agents was similar to that of low grade flours.

Discussion

In the first part of this study it was found that for experimentally milled, straight grade flours the maturing effect of Agene, Beta Chlora, and $KBrO_3$ was dependent on the protein content of the flours. The extent of the response to the reagents, and the amount of reagent necessary for maximum response was positively related to the amount of protein in the flour. No physico-chemical measurement has definitely demonstrated which characteristic of the proteins was altered. In the second part of the study it was found that apparently some constituent of the germ which contaminates the lower grade flours was also responsible for part of the response of the flours to maturing agents. A high grade flour to which powdered germ was added reacted to 3 gms. of Agene per barrel, similar to a clear flour, whether the germ powder was bleached apart from or after being mixed with the control flour. An important exception was noted in the fact that the addition of bleached germ did not increase the loaf volume of the mixture unless the control flour was also bleached. To corroborate this, raw germ was given an extremely heavy dosage of Agene with full sized Agene equipment. Mixtures of this heavily over-bleached germ with the control flour produced a loaf similar to the one with a 3-gram treatment. It

was found impossible to treat germ with Agene so that mixtures produced a loaf with the characteristics of over-bleaching. This would indicate that oxidizing agents have at least two effects—one on the germ constituents which contaminate flour, reducing their deleterious effect; and one on the proteins themselves, as is indicated by the influence of protein content on the action of the reagents, and also by the impossibility of over-bleaching, by over-bleaching the germ constituents separately.

Conclusions

By present analytical methods, no significant change in the inherent "quality" of the *proteins* of wheat flour has been detected when it is treated with nitrogen trichloride (Agene). That there is a change in the "quality" of the *gluten* formed when the flour is made into a dough is easily demonstrated by the feel of the washed gluten, the handling qualities of the fermenting dough, and by the characteristics of the baked loaf. The similarity of the action of nitrogen trichloride to other oxidizing agents suggests that the action is one of oxidation, and the minute quantities necessary for maturation suggests that they affect the colloidal properties of some constituents of the flour.

The present study suggests that reason for the poorer baking qualities of the lower grade flours is due to their contamination with germ particles, and that the improvement due to artificial maturation is caused by some reaction which apparently involves oxidation of some constituent of the germ content of the flour. The present study does not agree with the hypothesis that the phosphatides are the constituents responsible for this reaction but indicates that some other constituent is involved.

Baking tests with straight grade flours indicate that the maturing effect seems to be dependent to some extent on the protein content of the flour.

The action of nitrogen trichloride on flours containing added bran powder and germ powder indicates that lowgradeness of flour is principally caused by germ and not by bran contamination. If lowgradeness is caused by germ instead of bran contamination, as is generally believed, then the operative miller should turn his efforts towards germ elimination instead of trying to reduce ash content by reducing bran pulverization. The baking qualities of low grade flours can easily be improved by maturing agents, but the bleaching effect cannot eliminate the dull color of contaminated mill streams. Elimination of the source of lowgradeness would reduce the necessity for a heavy application of bleaching and maturing agents.

Acknowledgments

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THE DIGESTIBILITY OF CRUST AND CRUMB OF WHITE BREAD *IN VITRO*

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That the heating of gluten and casein to 150° C. decreases their nutritive value was shown in 1931 by Morgan. Later this led Kon (1931) to test the nutritive value of the crust and the crumb of white bread on rats. He found that those fed on the crumb of the bread grew better than those fed the crust. (Recently we have found the digestibility of baked casein to be less than that of raw casein.) Hence the question arises as to whether there is a difference in the digestibility of the crust and crumb of the white bread, which may account at least in part for the greater nutritive value of the crumb.

The bread used in this test was made as follows: One compressed yeast cake was dissolved in 2 cupfuls of warm water, one tablespoon of salt, two tablespoons of sugar, and enough flour was added to make a fairly stiff dough. The bread was permitted to rise twice then put in pans and allowed to rise a third time. The bread was baked in an oven at 210° C. The inside temperature of the loaf, forty minutes after it was placed in the oven, registered 90° C. and at the end of fifty-five minutes the temperature reached a maximum of 94° C. The loaf measured $3.5'' \times 4'' \times 7.5''$ when baked. After allowing the bread to cool, the inside of the loaf was carefully separated from the crust, and the top crust was kept separate from the bottom. The bread was then dried and finely ground.

Digestion experiments were made on each of the three samples, the crumb, the top crust, and the bottom crust. These products were put into solution by making a paste of 35 gms. with cold water, then adding about 75 cc. of boiling water. To this was added 20 cc. of N/10 sodium hydroxide, and the mixture allowed to cool, after which it was diluted to one liter. 10 cc. of this solution was titrated with sodium hydroxide, using cresol red as an indicator, to a reddish purple color. This amount of base was then added to the entire sample to obtain a pH of 8.1. This was done in order to secure the optimum activity of the digestive enzyme trypsin. From this amount two samples of 400 cc. each were heated to 40° C. in 500 cc. flasks, after 1 cc. of toluol was added. This was mixed with 10 cc. of a 5% solution of trypsin and a sample was taken to determine its amino nitrogen content by the Van Slyke method, and also by the Sörensen formol titration.

The Sörensen formol titration as modified by Northrop (1926) was carried out as follows: To a 20 cc. portion was added 10 cc. of formaldehyde which had been freshly prepared by adding 10 drops of phenolph-

TABLE I

AMINO N IN MILLIGRAMS OBTAINED FROM 1 GRAM OF BREAD PROTEIN AFTER VARYING INTERVALS OF *in vitro* DIGESTION WITH TRYPSIN

		Time intervals in hours											
			1		3		5		7		21		48	
Method	Bread portion	Initial	Total	Increase	Total	Increase	Total	Increase	Total	Increase	Total	Increase	Total	Increase
Formol titration	Top crust	16	29	13	39	23	46	30	52	36	60	44	84	68
	Bottom crust	16	33	17	44	28	52	36	56	40	66	50	93	77
	Crumb	17	39	22	48	31	56	39	60	43	73	56	99	82
Van Slyke	Top crust	31	50	19	55	24	67	36	73	42	82	51	87	56
	Bottom crust	32	52	20	58	26	73	41	81	49	88	56	104	72
	Crumb	32	57	25	69	37	78	46	87	55	96	64	111	79

thalein solution to 50 cc. of 40% formaldehyde and titrating with N/10 sodium hydroxide to a light pink color. The original solution is then titrated with N/10 sodium hydroxide to a light pink color.

The solutions were incubated at 40° C. and samples taken at intervals, to determine the increase in amino and carboxyl groups by the Van Slyke and formol titration methods.

In the Van Slyke (1912) amino nitrogen determinations, the micro apparatus was used, making it possible to measure very small amounts of nitrogen without reducing percentage accuracy. The 2 cc. sample was placed in the Van Slyke apparatus after the sodium nitrite and acetic acid had reacted with the evolution of nitrous acid. After shaking these and allowing the mixture of gases to collect in the tubes it was passed through an alkaline permanganate solution. The gas was then forced into the measuring burette to determine the quantity of nitrogen obtained from the sample used. The results are given in Table I.

Fats and carbohydrates often interfere with the Van Slyke amino-N determinations, but inasmuch as the results obtained by the Sörensen formol titration method, particularly the increases in amino-N for the intervals measured, correspond rather closely with these results, they can be looked on as fairly accurate.

The results as given in Table I indicate that the crumb of the bread digests more readily *in vitro* than does the crust and that crust on the top of the loaf is more slowly digested than that on the bottom of the loaf. The higher the temperature to which the bread dough was exposed apparently the more slowly was it digested.

In the past it has been the custom to feed to infants the crust of bread in preference to the crumb, because it was thought that since some of the starch of the crust is partially dextrinized it may be more easily digested. If *in vitro* digestion data apply at all to human digestion problems, since the infant and young child require a high protein diet of easy digestibility, it would seem to be advisable to feed the crumb rather than the crust because of the more digestible character as well as higher biological metabolic value of the proteins of the crumb.

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STUDIES ON TEST WEIGHT AND FLOUR YIELDING CAPACITY OF WHEATS [1]

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(Read at the Convention, June, 1933)

Test weight per bushel was used by the practical miller before the advent of grading systems as an index of flour-yielding capacity of wheat. At present it is the most important grading factor in the Federal standards for wheat.

That a close relationship does exist between test weight per bushel and the flour-yielding capacity of wheat has been shown by Thomas (1917). Mangels and Sanderson (1925) also found a high degree of correlation between test weight and flour yields for seven crops of North Dakota common wheat.

The effect of variety and other factors on the test-weight-flour-yield relationship has not been extensively studied. Thomas (1917) shows that Preston or Velvet Chaff is lower in flour-yielding capacity than either Blue Stem or Fife. Shollenberger and Clark (1924) have presented data on test weight and flour yield of American wheat varieties. They state "that although the test weight per bushel of dockage-free wheat is a fair indication of flour-yielding capacity, it does not always follow that the variety or class having the highest average test weight per bushel yields the highest average per cent of flour." This paper presents data on the effect of variety and other factors on the test-weight-flour-yield relationship.

Comparison of Flour-Yielding Capacity

The flour yield data presented were obtained from small samples milled on an Allis-Chalmers experimental mill. Test weight, in all cases, is on the dockage-free wheat.

A wheat variety, when grown under different environments, and different varieties when grown under the same environment, will show wide variation in test weight per bushel. In order to compare the intrinsic flour-yielding capacity of wheats of varying test weight, the *ratio*

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of total flour yield to test weight per bushel is used as a basis of comparison in this paper.

Effect of Variety on Flour-Yielding Capacity

The data in Table I compare twelve varieties of common wheat and three varieties of durum wheat, grown at Fargo and Dickinson, North Dakota, for the three years 1928, 1929, and 1930. Each average figure, therefore, represents six separate flour yield and test weight comparisons.

TABLE I

RELATION OF VARIETY TO FLOUR YIELD AND TEST WEIGHT

Three Year Average for 12 Varieties Grown at Fargo and Dickinson, 1928–1930

	Average test weight per bushel	Actual average flour yield	Ratio yield to test weight
	Lbs.	*P. ct.*	
Marquis	60.0	73.9	1.23
Ceres	59.2	76.0	1.28
Reward	62.5	73.6	1.18
Power	59.5	75.3	1.27
Hope	55.8	75.8	1.36
Marquillo	58.8	76.5	1.30
Quality	59.2	75.6	1.28
Garnet	58.2	75.2	1.30
Kota	59.5	75.2	1.26
Preston	60.3	73.3	1.22
Progress	60.6	70.9	1.17
Hurdsfield	58.8	68.8	1.17
Mindum		75.1	1.22
Kubanka		74.2	1.22
Pentad		69.8	1.16

Taking the figures for the variety Marquis as the standard for the common wheats, it will be noted that a number of the varieties listed are superior to Marquis both in actual flour yield and in the ratio of flour yield to test weight. These varieties are Ceres, Power, Hope, Marquillo, Quality, Garnet, and Kota. The variety Hope, in particular, shows a very high flour yielding capacity in relation to the test weight per bushel.

The varieties Reward, Preston, Progress, and Hurdsfield are lower than Marquis in both flour yield and ratio of flour yield to test weight. While the flour-yielding capacity of Preston is only slightly lower than that of Marquis, that of other varieties is significantly lower. Reward, for example, averages 2.5 pounds higher than Marquis in test weight, but averages less in actual flour yield. Progress with an average test weight of 60.6 pounds gave an average flour yield of only 70.9%.

The durum varieties—Mindum and Kubanka—are only slightly in-

ferior to Marquis in flour-yielding capacity. However, the flour-yielding capacity of the variety Pentad is much lower showing an average yield-weight ratio of only 1.16.

TABLE II

RELATION OF VARIETY TO FLOUR YIELD AND TEST WEIGHT

Average for 9 Varieties Grown at Different Points in North Dakota

	Ratio flour yield to test weight			
	1930[1]	1931[2]	1932[1]	Average 1930–1932
Marquis	1.26	1.25	1.27	1.26
Ceres	1.30	1.25	1.27	1.27
Reward	1.19	1.20	1.21	1.20
Hope	1.37	1.37	1.41	1.38
Marquillo	1.32	1.31	1.37	1.33
Reliance	1.27	1.26	1.28	1.27
Komar	1.29	1.29	1.30	1.29
Supreme	1.31	1.29	1.31	1.30
Minn. 2303	1.30	1.29	1.32	1.30

[1] Average 6 stations, Fargo, Dickinson, Langdon, Edgeley, Williston, Hettinger.
[2] Average 5 stations, Dickinson not included.

In Table II are presented additional data relative to the flour-yielding capacities of common wheat varieties. The data for the years of 1930–1932, both inclusive, cover three unusually dry years and the varieties listed are those which are of particular interest today.

The variety Hope again shows the highest flour-yielding capacity in relation to its test weight per bushel; the next highest is Marquillo. All varieties show a higher yield-weight ratio than Marquis except Reward which shows a ratio of 1.20 as compared to 1.26 for Marquis.

Seasonal Variation in Flour Yielding Capacity

Table III presents data for eight consecutive seasons obtained from the Fargo rotation and fertility plots. The variety of wheat in all cases was Ceres and the number of samples in the average figures ranged from 51 to 80.

The yield-weight ratio varies from 1.22 to 1.37. Apparently there is very little relation between variation in the yield-weight ratio and rainfall and temperature *during the growing season.*

Post-harvest rainfall, however, appears to be an important factor. For 1928, the ratio of flour yield to test weight per bushel was 1.37 and the August rainfall was 6.42 inches. This excessive rainfall was responsible for considerable damage to the shocked grain. The average test weight of this damaged grain was only 53.8 pounds per bushel, but the yield-weight ratio is 1.37. This would indicate that weathering and

sprout damage injures the flour-yielding capacity of wheat much less than the decrease in test weight would indicate.

TABLE III

SEASONAL VARIATION OF YIELD-TEST WEIGHT RATIO

Ceres Wheat from Rotation Plots at Fargo

Year	Number of samples from plots	Average test weight	Average flour yield—test weight ratio	Mean June temperature	Mean July temperature	Rainfall May, June, July	Rainfall August
		Lbs.		*° F.*	*° F.*	*Inches*	*Inches*
1925	71	60.8	1.23	64.4	68.2	11.95	.25
1926	59	60.3	1.23	60.2	70.2	6.94	1.83
1927	51	60.9	1.25	62.7	66.0	8.92	2.02
1928 [1]	70	53 8	1.37	60.2	69.3	10.76	6.42
1929	80	61.9	1.22	64.0	71.5	2.37	0.75
1930	58	61.9	1.23	65.0	73.6	5.86	0.92
1931 [2]	62	58.0	1.26	69.0	72.5	9.93	1.85
1932	62	59.0	1.28	68.9	72.1	5.57	2.48

[1] Grain badly sprouted due to heavy post-harvest rains.
[2] Slight damage due to weathering.

Some sprout damage was present in 1931, but not to such an extent as in 1928. The yield-weight ratio in this case is 1.26. High yield-weight ratios occurred also in 1927 and in 1932, and the August rainfall in both cases was greater than 2 inches. The data available would indicate that post-harvest conditions rather than seasonal variation during the growing period is the important factor.

Regional Variation

Table IV compares the average test weight, flour yield and yield-weight ratio for three varieties of common wheat and three varieties of durum wheat grown continuously at Fargo and Dickinson during the ten years—1923–1932.

TABLE IV

REGIONAL VARIATION IN TEST WEIGHT AND FLOUR YIELD

	Fargo [3]			Dickinson [3]		
	Average test weight	Average flour yield	Average ratio	Average test weight	Average flour yield	Average ratio
	Lbs.	*P. ct.*		*Lbs.*	*P. ct.*	
Common wheat [1]	59.3	74.9	1.27	59.2	73.9	1.25
Durum wheat [2]	61.7	73.6	1.20	61.0	74.3	1.22

[1] Three varieties, Marquis, Ceres, Powers.
[2] Three varieties, Kubanka, Mindum, Pentad.
[3] Average for 10 years—1923–1932.

The three hard red spring varieties were Marquis, Ceres, and Powers. It is interesting to note that the average test weight for the ten years for these three varieties is practically the same for both locations. The flour yield from the Fargo samples is higher, but this is probably due to greater post-harvest damage at Fargo which would reduce test weight without a corresponding reduction in flour-yielding capacity.

The three durum varieties (Kubanka, Mindum, and Pentad) show a better flour-yielding capacity when grown at Dickinson.

The test weight figures are interesting. Two of the common wheat varieties used in the average are quite susceptible to rust, but the Fargo grown wheat averaged slightly higher in test weight for the ten year period. Rust injury to test weight is much greater at Fargo than at Dickinson, but this is evidently compensated for by the greater amount of heat and drouth injury at Dickinson.

The durum wheats, being more resistant to rust than Marquis or Powers, show a significantly higher average test weight at Fargo as compared with those at Dickinson. Heat injury is an important factor, affecting test weight of durums grown at Dickinson.

Summary

1. Wheat varieties show significant varietal variation in flour-yielding capacity as related to test weight.

2. Seasonal variation during the growing period is less important in effect on the flour yield and test weight relationship than post-harvest conditions while grain is in the shock.

3. Regional variation apparently is not extremely important in affecting flour-yielding capacity.

Literature Cited

Mangels, C. E., and Sanderson, T.
1925 Correlation of test weight per bushel of hard red spring wheat with flour yield and other factors of quality. Cereal Chem. **2**: 365–369.

Shollenberger, J. H., and Clark, J. Allen
1924 Milling and baking experiments with American wheat varieties. U. S. Dept. Agr. Bull. 1183.

Thomas, Levi M.
1917 A comparison of several classes of American wheats and a consideration of some factors influencing quality. U. S. Dept. Agr. Bull. 557.

ANNUAL REPORT OF SECRETARY-TREASURER

M. D. Mize

January 1, 1934

After four years of such uncertain financial conditions, it is a pleasure for your Secretary-Treasurer to submit a report for 1933 showing a safe financial gain in all activities of the Association. Believing that the statement form developed three years ago displays a clear financial picture of the Association, this year's report has been compiled in the same manner. Therefore, a true comparison can be made between the reports for the past four years. Every member should experience a feeling of pride and satisfaction in the many activities undertaken by our Association during the past nineteen years, while at the same time, the Association has grown in financial strength through the co-operative effort of every member. The rapid advancement of the science of cereal chemistry during this period would have hardly been possible without the existence of our Association.

DETAILED MEMBERSHIP STATEMENT DECEMBER 31, 1933

	Total	Active	Corp.	Hon.
Membership, Dec. 31, 1932	460	412	46	2
New members added during 1933	25	23	2	0
Members reinstated	7	7	0	0
Members resigned and suspended for non-payment of dues during 1933	44	39	5	0
Members deceased	2	2	0	0
Members in good standing Dec. 31, 1933	446	401	43	2

PROFIT AND LOSS STATEMENT

January 1 to December 31, 1933

RECEIPTS 1933			
Cereal Chemistry			
Membership dues			
Active		$1,410.50	
Corporation		430.00	
Subscriptions, reprints, back numbers and advertising	$2,498.73		
1933 Subscriptions received in 1932	729.21		
1933 Accounts Receivable	84.54		
1932 Income received in 1933	71.47		
Net 1933		3,241.01	
Interest on Invested Funds		129.04	
Total Net Receipts 1933			$5,210.55

Association			
Membership dues		1,403.50	
Application Fees		70.00	
Interest on Invested Funds		138.92	
Miscellaneous Income		28.00	
Chicago Convention Registration Fees (A)		183.05	
Total Net Receipts 1933			1,823.47
Book of Methods Reserve Fund			
Interest on Invested Funds			76.00
Convention Reserve Fund			
Interest on Invested Funds		73.78	
Balance of Chicago Registration Fees (B)		71.46	
Total Net Receipts 1933			145.24
Experimental Baking Fellowship Fund			
Interest on Invested Funds			.91
TOTAL RECEIPTS OF ALL ACCOUNTS 1933			$7,256.17

DISBURSEMENTS 1933

Cereal Chemistry			
Cost of printing Journal and Reprints	$3,033.14		
Cost of editing and miscellaneous expenses	1,103.72		
1933 Accounts Payable	1,082.39		
1932 Accounts Uncollectable	17.75		
1932 Accounts paid in 1933	*123.14*		
Net Disbursements 1933		$5,113.86	
Surplus 1933			$ 96.69
Association			
Expenses of President, Vice-President Office, News Letter	247.73		
Expenses of Sec'y-Treas.'s Office	355.68		
Committee Expenses	20.39		
Chicago Convention Expenses	183.05		
Chicago Convention Report	$ 85.55		
Chicago Convention Report Accounts Payable	182.44	*267.99*	
Osborne Medal Brochure	221.01		
Miscellaneous Expenses	45.09		
1932 Accounts paid in 1933	*150.00*		
Net Disbursements 1933		1,190.94	
Surplus 1933			632.53
Book of Methods Reserve Fund		---	
Surplus 1933			76.00
Convention Reserve Fund		---	
Surplus 1933			145.24
Experimental Baking Fellowship Fund		---	
Surplus 1933			.91
TOTAL DISBURSEMENTS OF ALL ACCOUNTS		$6,304.80	

DISTRIBUTION OF NET ASSETS

Cereal Chemistry Assets 1932	$2,997.43	
Surplus 1933	96.69	
Assets Dec. 31, 1933		$3,094.12
Association Assets 1932	2,145.25	
Surplus 1933	632.53	
Assets Dec. 31, 1933		2,777.78
Book of Methods Reserve Fund 1932	375.98	
Surplus 1933	76.00	
Assets Dec. 31, 1933		451.98
Convention Reserve Fund 1932	452.78	
Surplus 1933	145.24	
Assets Dec. 31, 1933		598.02
Experimental Laboratory Baking Fund 1932	83.79	
Surplus 1933	.91	
Assets Dec. 31, 1933		84.70
		$7,006.60

FINANCIAL STATEMENT DECEMBER 31, 1933

U. S. National Bank—Checking Account	$ 269.35
Cash on Hand	642.87
U. S. National Bank—Savings Dept.	18.27
First National Bank—Savings Dept.	258.62
Petty Cash Fund in Washington, D. C.	200.00
Building & Loan Stock in Kansas City	2,000.00
Building & Loan Stock in Omaha	1,000.00
Building & Loan Stock in Minneapolis	1,797.78
U. S. Treasury Bonds	2,000.00
1933 Accounts Receivable	84.54
GROSS ASSETS	8,271.43
LIABILITIES	
1933 Accounts Payable	*1,264.83*
NET ASSETS	$7,006.60

Note: All amounts in italics are negative amounts and are subtracted from the other amounts in the same column.

REPORT OF AUDITING COMMITTEE

G. R. STADLER, *Chairman*

The Auditing Committee has examined the books of the Secretary-Treasurer for the fiscal year January 1, 1933 to December 31, 1933 and find the same to be correct.

In looking over the accounts and assets we believe that the financial report of the Secretary-Treasurer displays the true financial condition of the Association.

BOOK REVIEWS

Food Products. By Henry C. Sherman. Published by The Macmillan Co., New York, 1933. 674 pp. Price $3.00.

This is the third edition of Sherman's well known text, the earlier editions having appeared in 1914 and 1924, respectively. The arrangement of material is essentially similar to that of the preceding edition, being divided into the following chapters: The principal constituents and functions of food; general aspects of food control; milk; milk products other than butter; eggs; meats and meat products; poultry, game, fish, and shellfish; grain products; vegetables; fruits and fruit products; nuts; edible fats and oils; sugars, syrups and confectionery; food adjuncts, unclassified food materials, and extra foods; and some aspects of food economics. In addition there are several appendices covering food laws and regulations, and the calcium, phosphorus, iron, copper, manganese, and vitamin content of numerous common foods. The text discussion of certain of these minerals has been amplified in this last edition, and the tabulation of the quantity present in foods (Appendix C, p. 622) has also been added.

This book, as the title suggests, is not primarily a discussion of nutrition or metabolism, although these subjects are not overlooked by the author. It is, indeed, a text-book of food technology, with passing reference to the more significant and unique nutritional qualities of each type of food-stuff. For a concise discussion of the handling and processing of common American foods this is a very convenient and useful manual. Each section is concluded with an extensive list of suggested readings which appear to be well chosen.

In addition to the notes on the Federal and State food laws and regulations, Sherman has laid proper emphasis (Chapter II) upon the development of grading systems to supplement the minimum standards of purity. He has called attention to the growing cooperation within certain food industries, and between those industries and the food officials in improving and standardizing food products. Reference is also made to the activities of the Committee on Foods of the American Medical Association in discouraging unwarranted claims and statements made respecting approved foods, both on the packages and in advertising.

The reviewer feels that the rational development of individual, and mass nutrition in America is facilitated by the careful attention which certain leaders in this field, including Sherman, have given to food production and technology. In this way they avoid pitfalls that are open before the theorists who fail to keep informed concerning the evolution of agrotechny and engineering practice, which determine, in no small measure, the relative availability of various foods to common folk.

C. H. Bailey

The Brewers Technical Review. Published monthly by the Siebel Publishing Company, 960 Montana Street, Chicago, Illinois. Subscription rates —United States $5.00 per year, Canada $5.50, all other countries $6.00.

This new publication is an off-spring of the Siebel Technical Review, and as the title indicates it is devoted entirely to brewing technique. The first two numbers illustrate that it is a very welcome contribution to the present day literature on brewing, discussing as it does the source of material for the brewing industry, the technicalities of plant operation, as well as the business affairs, namely, accounting and production control, in the management of today's breweries.

The articles are written in a semi-technical way and in understandable language, and each article is suitably illustrated. A worth while abstract section, as well as a section devoted to book reviews and patent notifications relating to malting and brewing, appears in each issue.

The new journal should be useful to all those cereal chemists interested in the malting and brewing industry.

D. A. Coleman.

The Foundations of Nutrition. By Mary Swartz Rose, Ph.D. Published by The Macmillan Company, New York, 1933. Revised edition. 630 pp. Price, $3.00.

This is the second edition of this valuable book. The number of pages has been increased from 501 to 630 in order to cover new material that has appeared since the publication of the first edition. There are several new illustrations and charts.

The first five chapters cover the subject of energy metabolism and energy requirement. Much of this material has been rewritten and expanded. Chapter six has to do with a shortage and surplus of calories and adequately covers the subject of underweight and overweight. An entirely new arrangement has been used in presenting the subject matter on proteins, mineral elements, vitamins and water. The mineral elements and water are considered both as body builders and body regulators. The discussion of iron and its relation to anemia is more adequately given than before. The recent findings on the effect of copper on the utilization of iron is touched upon.

An entire chapter devoted to each of the six vitamins includes a brief history of their discovery, and description of method of measurement and a comprehensive discussion of their physiological importance. The important food sources are then given and the daily requirement is estimated as well as is possible from the data available. These suggested daily requirements, very ingeniously derived, are a decided contribution.

Chapters 16 through 22 discuss the contributions to the diet made by different foods classified in four main groups. Milk is discussed in a chapter by itself because of the important place that it holds in the diet.

The share system described in the first edition is again used and makes possible the comparison of food values in a very graphic way. Four chapters deal with diets for the different age groups and for the family as a whole. A brief discussion of moderate and minimum cost diets is included. In the last chapter attention is given to the special food needs of mothers and babies.

Table I of the appendix giving the nutritive values of edible portions of foods has been greatly improved and expanded. There is a brief description of each food which will be greatly appreciated by those who make practical use of the information in the table. The amounts of each food are given by weight in grams and ounces and also by measure. The vitamin values are in many cases expressed in units.

This book presents the important phases of the subject of nutrition in a readable, easily intelligible, accurate and very useful form. It should prove invaluable to the lay reader interested in this subject as well as to those engaged in research and the dissemination of information on nutrition.

H. E. Munsell